NATIONAL ENERGY AUTHORITY

KINGDOM OF THAILAND

PRE-FEASIBILITY REPORT

KHLONG THA DAN HYDROELECTRIC PROJECT

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OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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JULY 1971

OVERSEAS TECHNICAL COOPERATION AGENCY

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Preface

In January 1971, the Government of Thailand made a request to the Gevernment of Japan for technical cooperation in conducting a pre-feasibility study of the Khlong Tha Dan Hydro-Electric Development Project located in Central Thailand and a reconnaissance study for the Nam Pai Hydro-Electric Power Development Project in the north-western part of this country. In compliance with this request, the Government of Japan entrusted the Overseas Technical Co-operation Agency (OTCA) with the performance of these aforementioned studies.

Taking the features of the said projects into account, OTCA dispatched to Thailand a survey team composed of five members from the Electric Power Development Co., Ltd. for the purpose of undertaking field surveys and collecting necessary data during the period from February 3 through March 19, 1971.

After their return to Tokyo, the survey team carried out a series of studies in connection with these projects in full collaboration with well-qualified experts and specialists of the said firm and prepared this report based upon the results of the field studies as well as data obtained during the team's stay in Thailand.

It is reported that the economic situations in the majority of Asian countries are stagnant while the Thai economy has been advancing at a remarkably rapid tempo. During the period of the first economic development plan (1961-1966), her annual economic growth reached 7.2%, and that for the first three years after the commencement of the second economic development plan (1967-1971) grew at a rate of 7.6%. Approximately 30% of the gross domestic product of Thailand is occupied by her agricultural sector with the mining and industrial sectors accounting for 16% of the total. The manufacturing industries have recently been increasing by approximately 12% on the average per annum. Besides, electric power consumed by the industrial sector comprises more than 60% of the total power consumption in Thailand. With an increase of production in the mining and industrial sectors, a large increment in their consumption of electric power can be aniticipated.

For these reasons, it is my sincere hope that this report will be of help in the formulation by the Government of Thailand of its long-range power development programs and the determination of guidelines for conducting the required investigations in the future.

On behalf of OTCA, I would like to take this opportunity to express my heartfelt gratitude for the hospitality and kind cooperation which officials of the Government of Thailand and associated organzations extended to the team during their stay in Thailand.

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Keiichi Tatsuke, Director General
Overseas Technical Cooperation Agency

Sir :

Submitted herein is a Pre-Feasibility Report regarding the Khlong Tha Dan Electric Power Development Project, Thailand.

The Overseas Technical Cooperation Agency (hereinafter called OTCA), for the purpose of pre-feasibility investigations of the Khlong Tha Dan Project and reconnaissance survey of the Nam Pai Project, sent a survey team consisting of five experts of the Electric Power Development Co., Ltd. (hereinafter called EPDC), to Thailand from February to March 1971. The survey team, based on "Report of Reconnaissance of Khlong Tha Dan Basin" submitted to the government of Thailand by OTCA in June 1965, carried out on-site field investigations of topography, geology, construction materials and hydrology. It also investigated the electric power demand and supply conditions, while also collecting other information necessary for planning.

The survey team, on return to Japan, based on the results of field investigations and information collected, performed analyses of hydrologic data, made load forecasts, carried out rough designs, estimated approximate construction costs, compared alternative plans and evaluated the economics in preparation of this Report, at the head office of EPDC under the direction of the Chief Engineer and with the cooperation of engineers of the company.

A major point of the Khlong Tha Dan Power Development Project is to effectively utilize a head of approximately 300 meters of a waterfall named the Heo Narok at the Khlong Pun site on the upstream part of the Khlong Tha Dan River. It has been found that by taking advantage of this head, it would be possible to develop this Project as a hydroelectric power source for peak loads with a capacity of 120 to 540 megawatts.

Since the location of the Project is at a close distance to Bangkok of only 120 kilometers, transmission of power to Bangkok, where there is great demand of power, can be easily accomplished. Further, in the future, should thermal power stations and nuclear power stations of large-capacity be constructed in Bangkok, by effectively utilizing the midnight surplus power of these stations for this Project, it would be possible to develop this Project as a power project of pumped-storage type.

In this Report, three possible alternative plans, which would be developed as mentioned above, have been selected from the numerous plans conceivable. The most advantageous plan of development should be ascerted in a feasibility study which would be carried out in the future.

In addition, this Project will have an effect not only in the aspect of electric power development, but also in the aspects of irrigation development of downstream areas and of development of tourism in the project area. There should be a necessity to carry out surveys and talks among the Thai authorities regarding these two aspects..

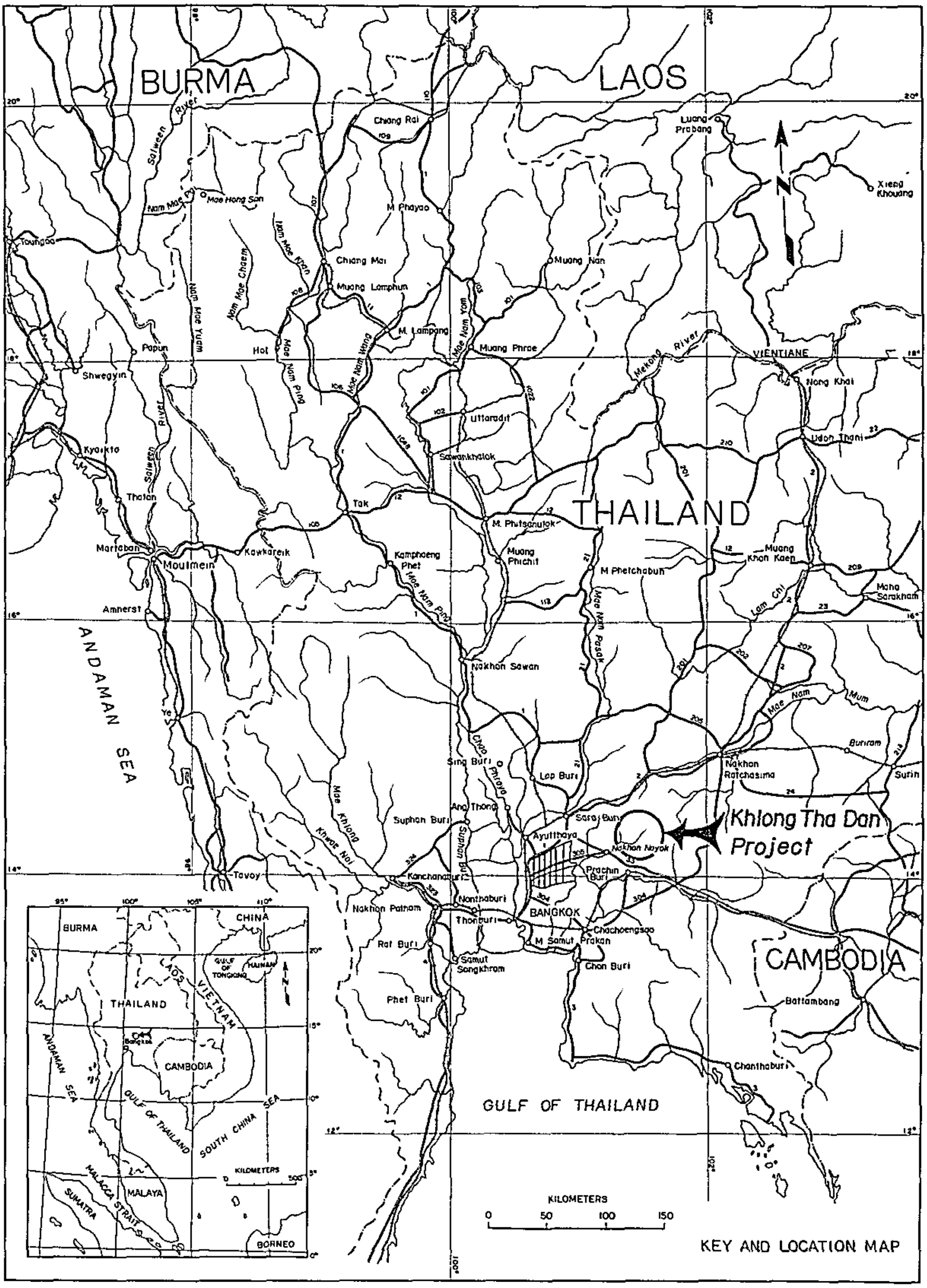
In closing, it is wished to express the heartfelt gratitude to Mr. Nitipat Jalichan, Secretary General of the National Energy Authority, and the officials concerned of the National Energy Authority, the Electricity Generating Authority of Thailand, the Royal Irrigation Department, the Department of Land Development, the Royal Forestry Department, the Department of Technical and Economic Cooperation, the local government office of Nakhon Nayok Province of Thailand, the Embassy of Japan, the Government of Japan and the OTCA for their great assistance and cooperation in carrying out the survey.

Yours respectfully,

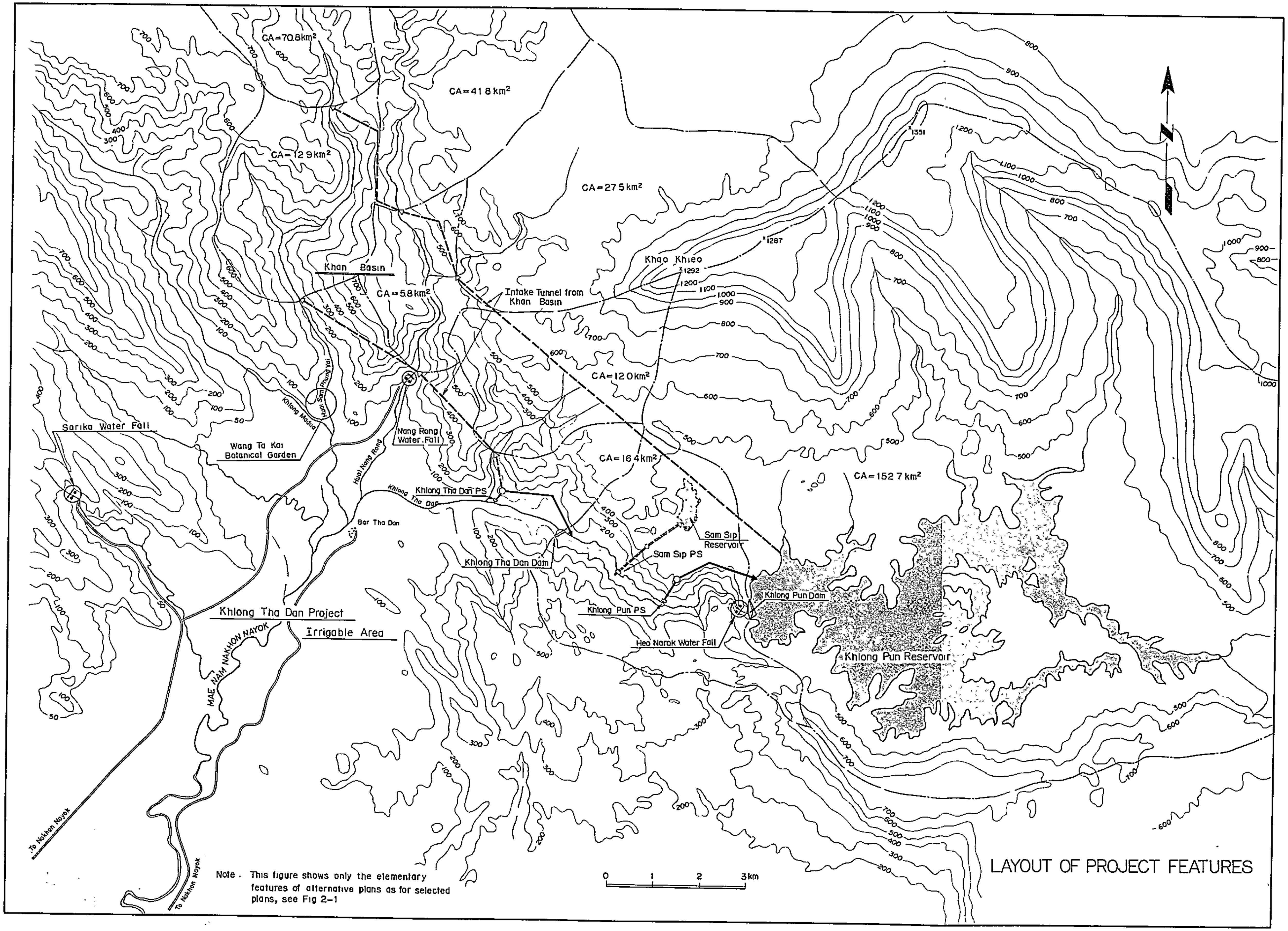
Mitsuharu Sato

Mitsuharu Sato, Chief
Thailand Khlong Tha Dan
and Nam Pai Survey Team

July 1971



KEY AND LOCATION MAP



LAYOUT OF PROJECT FEATURES

Note . This figure shows only the elementary features of alternative plans as for selected plans, see Fig 2-1

Unit and Conversion of Unit

mm	:	Milimeter
cm	:	Centimeter
m	:	Meter
km	:	Kilometer
sq. mm	:	Square milimeter
sq. cm	:	Square centimeter
sq. m	:	Square meter
sq. km	:	Square kilometer
ha	:	Hectare
cu. m	:	Cubic meter
gr	:	Gram
kg	:	Kilogram
ton	:	Metric ton
m/sec	:	Meter per second
c.m.s.	:	Cubic meter per second
cu.m.s.-day	:	Cubic meter per second - day
kW	:	Kilowatt
kWh	:	Kilowatt hour
MW	:	Megawatt
kV	:	Kilovolt
kVA	:	Kilovolt - ampere
MWh	:	Megawatt - hour
r.p.m.	:	Revolutions per minute
EL	:	Height above mean sea level
^{o}C	:	Degree in Centigrade
p.p.m.	:	Parts per million by weight
%	:	Percentage
$	:	U.S. dollar
฿	:	Baht
1 ha	:	10,000 sq.m, 6.25 rai
1 rai	:	1,600 sq.m, 0.16 ha
1 MW	:	1,000 kW
1 $	:	100 cent, 1,000 mill, 20.8 Baht, 360 Yen
1 ฿	:	100 Satang, 0.0481 dollar, 17.31 Yen

Terms

Changwat	A political subdivision of the Kingdom of Thailand; the English equivalent is province.
Amphoe	A political subdivision of a province (changwat); the English equivalent is district.
Ban	A village
Mae Nam	A large river.
Nam	A medium-sized river.
Lam	A small river.
Huai	A rivulet.
Khlong	A stream
Khao	A mountain, a hill
GDP	Gross Domestic Product is GNP less net income earned abroad.
GNP	Gross National Product represents the total monetary value in current prices of goods and services produced for sale in a given year plus an estimate of certain outputs (goods and services) that are neither bought nor sold. GNP is a useful means of measuring the economic growth of a country.

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CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Authorization and History

The population and the GNP, which is generally an index of a national economic development, of Thailand have recently shown annual growth rates of 3% and 8% respectively. In parallel with these growths, the Thailand's power demand has shown an extremely prominent growth rate averaging 22% annually. Particularly, this trend is prominent in the capital city of Bangkok and in its surrounding area. In order to cope with this increase in power demand, the National Energy Authority (hereinafter called NEA) has been planning hydroelectric power development in the Khlong Tha Dan River basin located 120 km northeast of Bangkok and also in the Nam Pai River basin near the city of Chiang Mai, the second largest city in Thailand. On 19 January 1971, Department of Technical and Economic Cooperation, on behalf of NEA, requested the Government of Japan to conduct a pre-feasibility survey of the Khlong Tha Dan River and a reconnaissance survey of the Nam Pai River. In response to this request, the Government of Japan commissioned the Overseas Technical Cooperation Agency (hereinafter called OTCA) to carry out this undertaking. OTCA, in view of the fact that the main purpose of this program was electric power development, organized a Survey Team comprised of the five persons listed below from the Electric Power Development Co., Ltd. (hereinafter called EPDC) and sent it to Thailand on February 3, 1971.

			Period
Chief	Mitsuharu Sato	Civil Engineer	3 Feb 1971 19 Mar 1971
Member	Hideharu Kashiwagi	Geologist	3 Feb 1971 19 Mar 1971
Member	Tsutomu Kidahashi	Electric Engineer	3 Feb 1971 19 Mar 1971
Member	Katsunori Hashimoto	Planning Engineer	3 Feb 1971 4 Mar 1971
Member	Azuma Tsunoda	Civil Engineer	3 Feb 1971 19 Mar 1971

The Survey Team, upon returning to Japan, from 20 March to 20 June 1971, based on the information gathered locally, carried out studies of this Project at the head office of EPDC under the direction of the Chief Engineer and with the cooperation of engineers of the company. Analyses of hydrologic data, load forecasts, comparison studies of development schemes, economic evaluation and other works were performed for the preparation of this Report.

This Report is concerned with the Khlong Tha Dan Project out of the two projects for which surveys were conducted.

1.2 Scope of Report

There are two existing reports concerned with the Khlong Tha Dan Project.

1) "Report on Reconnaissance of Khlong Tha Dan Basin," Overseas Technical Cooperation Agency, Government of Japan, June 1965.

2) "Desk Study of Khlong Tha Dan Project, " National Energy Authority, May 1970.

These reports briefly describe schemes of developing this Project as conventional hydroelectric power development and as pumped-storage hydroelectric power development.

The purpose of this Report is to reexamine possibility of these two methods of power development, to select optimum plans for the respective cases and to make recommendations necessary for a feasibility study that would be made in the future.

In the course of the field investigations, a land at the downstream area of the Khlong Tha Dan River was found to be promissing for irrigation, and a very brief,tentative study is added in this regard.

1.3 Basic Data

Data gathered in the field investigations are indicated in Appendix A-3. This Report has been prepared based on these data.

CHAPTER 2

SUMMARY AND RECOMMENDATIONS

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CHAPTER 2. SUMMARY AND RECOMMENDATIONS

2.1 Summary

At the present time, according to analyses based on limited information, it would be appropriate to develop the Khlong Tha Dan Project mainly for the hydroelectric power generation to meet peak loads in which regard the following three alternative plans are identified as potentially attractive. (See Fig. 2-1)

1) Plan of Development of Conventional Type (Plan C):

As a result of study of several conventional plans of hydroelectric power development (without considering pumped-storage power development), plan C is the most promising of those plans. Plan C is a plan to construct the Khlong Pun Dam, 62 m high, on the upstream part of the Khlong Tha Dan River to create a reservoir, taking water of the adjacent Khan River Basin into this reservoir and generating 120 MW of power at an outdoor type powerhouse in the downstream of the dam. The annual benefit-cost ratio of this plan, when the period of analysis is taken to be 50 years, would be approximately 1.1 and the plan C is idnetified as potentially attractive.

2) Plan of Development of Pumped-Storage (Plan R):

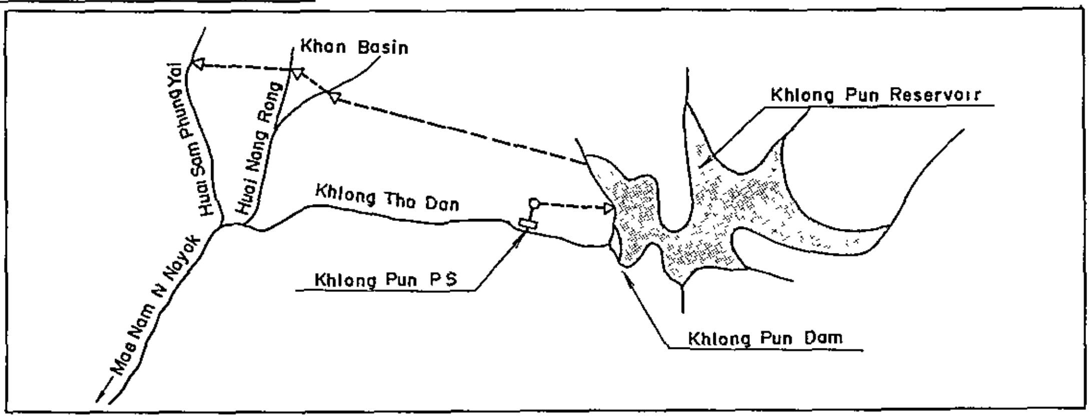
Leaving the layout and power generation facilities of the abovementioned plan C unaltered, the Khlong Tha Dan Dam, 56 m high, and a 20-MW, outdoor type power plant are further to be built in the downstream of the Khlong Pun Dam. In addition to this layout, on the right bank side of the Khlong Tha Dan Reservoir at a terrace of comparatively high elevation, the Sam Sip Upper-Reservoir is to be created and a recirculating type underground pumping-up station of 400 MW is to be built with the Khlong Tha Dan Reservoir serving as the lower reservoir. The total output of the Project would then be 540 MW. The annual benefit-cost ratio, when the period of analysis is taken to be 50 years, would be approximately 1.1 and the plan R is identified as potentially attractive.

3) Plan of Development of Pumped-Storage (Plan M):

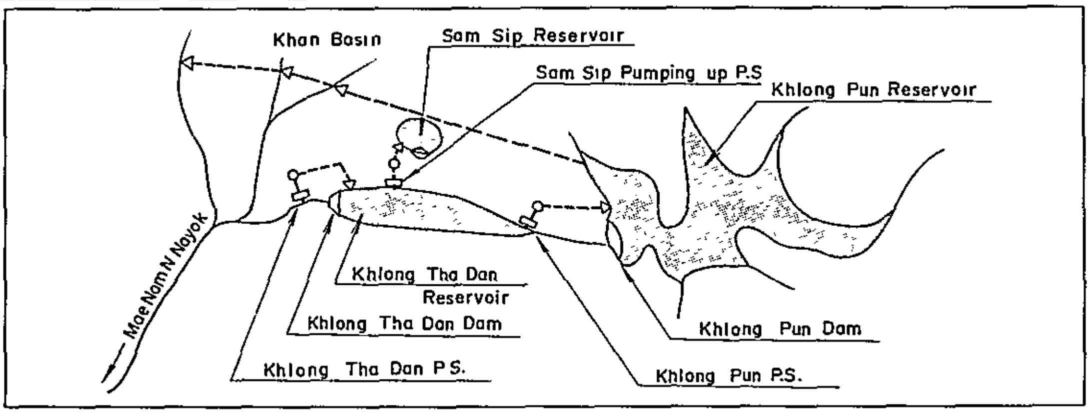
The Khlong Tha Dan Dam is to be constructed downstream of the Khlong Pun Dam of the abovementioned plan C to provide the Khlong Tha Dan Reservoir. However, the Khlong Pun Power Station unlike in plan C would be an underground type, and the plan is to utilize the Khlong Tha Dan Reservoir as the lower-reservoir and the Khlong

Fig 2-1 Plans of Layout of Selected Alternative Plan

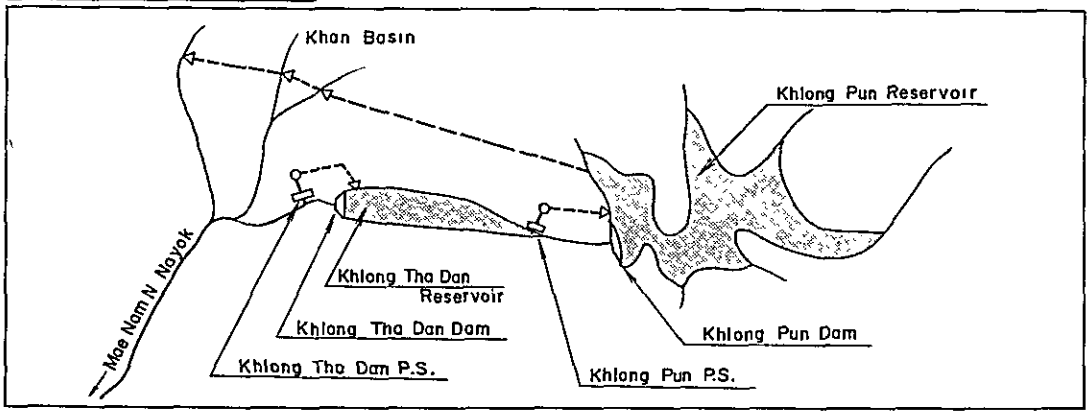
Alternative Plan C



Alternative Plan R



Alternative Plan M



Pun Reservoir the upper-reservoir to provide a multi-use type pumping-up station with an output of 400 MW. The total output of the Project would then be 420 MW. The annual benefit-cost ratio, when the period of analysis is taken to be 50 years, would be approximately 1.0 and the plan M is identified as potentially attractive.

Which of the three cases above would be the best plan of development would be determined in a feasibility study after studies of aspects of electric power in Thailand such as the future growth in power demand and further detailed surveys of the physical features of the Project.

In regard to the aspect of electric power, according to this pre-feasibility grade study, the energy demand and the peak demand in 1980 will be 15,900 x 10^6 kWh and 3,000 MW respectively. For this reason, electric power development, both hydro and thermal, has become an urgent problem and this Project would be considered in this light.

Due to such a situation, a nuclear power station would be provided during the period from 1970 to 1980. On the one hand, the present pattern of power consumption has a conspicuous peak at the lighting-up time in the evening. Taking these two aspects into account, it should become necessary to develop pumped-storage power stations to satisfy the future peak demand of power, utilizing available surplus energy of both thermal and nuclear power stations at midnight. The Khlong Tha Dan Project would consist of hydroelectric power stations with high heads rarely seen in Thailand. Further, it is located at a close distance from Bangkok of only 120 km. It has therefore a possibility of becoming a promising pumped-storage power source.

According to results of surface reconnaissance of the project sites, it seems that there would be no unusual problems in engineering design and construction.

Water used for power generation in this Project can again be utilized as irrigation water in the downstream area. Especially, water taken from the Khan Basin will increase the irrigational benefit to the area. The irrigable area in the dry season would be approximately 6,400 ha and the surplus benefit from this could be expected to be about ฿1,500 per ha annually.

On the other hand, due consideration should be given to the sight-seeing spots, for example, by releasing some quantity of water for the water-falls, although its negative effect on power generation would be considerably smaller than the invaluable benefit of people's recreation.

2.2 Recommendations

(1) From the above conclusions, the Project is thought to be promising and it is recommended for a feasibility study to be made. For this purpose, it is recommended to carry out the two items below.

(2) Provision of topographical maps, performance of geological survey works and continuing compilation of hydrologic and meteorological data. (See Chapter 9)

(3) Further investigation and study in the feasibility study on the following items in regard to pumped-storage power generation:

- i) Role of pumped-storage power generation in the power system of Thailand,
- ii) Capacity of appropriate pumped-storage power generation,
- iii) Timing of pumped-storage power development and stage development of Project,
- iv) Surplus energy of nuclear and/or thermal power stations, and
- v) Cost per kWh when surplus energy is to be utilized as power for pump-up.

CHAPTER 3
OUTLINE OF PROJECT AREA

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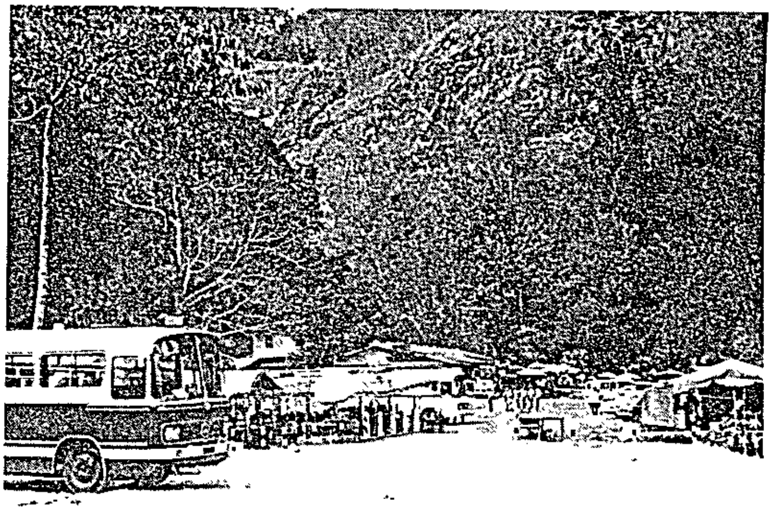


Photo. 3–1 Sight-seeing Spot (Sarika Water-fall)

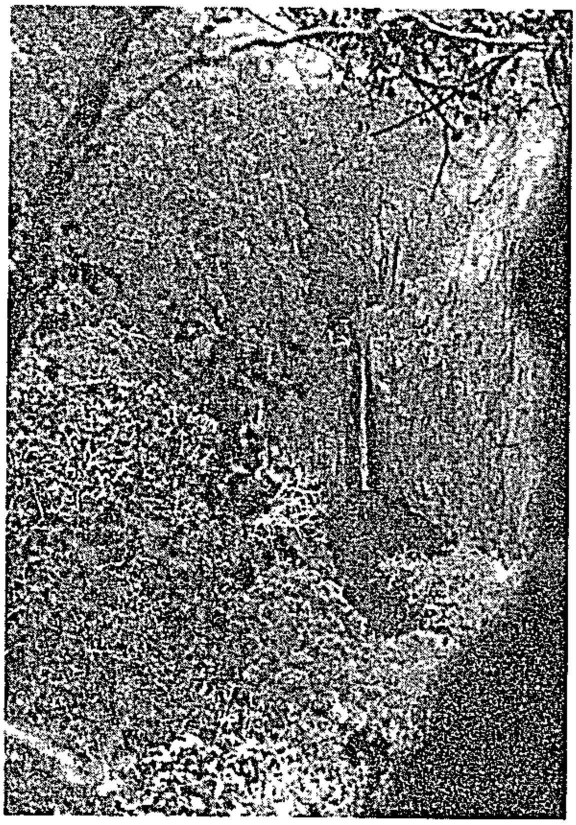
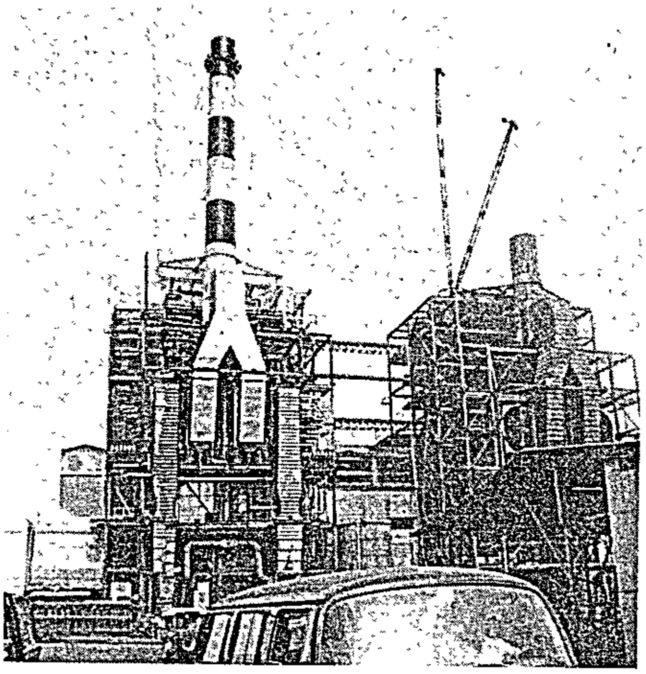


Photo. 3–2 Third Fall of Heo Narok Waterfall in Jungle



Phto. 3–3 South Bangkok Thermal Power Plant Under Construction

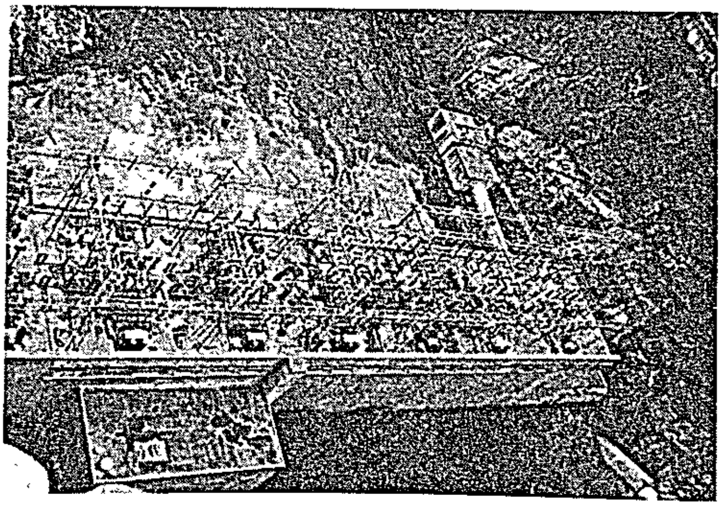


Photo. 3–4 Bhumibol Hydroelectric Power Station in Operation

CHAPTER 3. OUTLINE OF PROJECT AREA

3.1 General Geography

On the northern side of Nakhon Nayok City, only 100 km northeast of the capital city of Thailand, Bangkok, Mt. Khao Khieo rises up to an elevation of approximately 1,300 m. Due north from this mountain, the Dong Phraya Fai Mountain Range extends in a band 80 – 20 km wide to the Mekong River. Also, due east from this mountain to the Mekong River, the Phanon Dang Paek Mountain Range extends similarly in the form of a band. In other words, these two mountain ranges are connected at Mt. Khao Khieo in an L-shape to divide Thailand into the Central Region and the Northeastern Region (Khorat Plateau). Part of this connection area has been designated by the Government as Khao Yai National Park in which the Khlong Tha Dan project area is situated. (See Fig. 3-1)

The southern side of Mt. Khao Khieo is the Khlong Tha Dan Project area. The Khlong Tha Dan River has its fountainhead in this mountain range and flows from east to west, and merges with the Nakhon Nayok River.

The Nakhon Nayok River midway in its flow runs through the city of Nakhon Nayok and joining the Mae Nam Bang Pakhon which flows into the Gulf of Thailand near Chachoengsao east of Bangkok. (See Fig. Key and Location Map)

The major cities in the area surrounding the project area are Bangkok, Nakhon Nayok, Sara Buri and Pranchin Buri to the south and Nakhon Ratchasima (or Khorat) to the north.

Bangkok is the capital of Thailand and is the largest city of the country. Nakhon Ratchasima following Bangkok and Chiang Mai is the third largest city of Thailand. Nakhon Nayok, Sara Buri and Prachin Buri are all capitals of provinces called changwat and the populations are 20,000 to 50,000.

The population of the capital, Bangkok, was approximately 1,700,000 according to the census of 1960, but in 1963 it had reached approximately 2,100,000 for an increase of approximately 23.8% in a period of 3 years. Therefore, if the population has continued to increase at the same rate, it is estimated it would presently be more than 3,500,000.

At Bangkok, an infrastructure of communications, transportation and electric power has been built up and the city is the center of commerce and industry. Also, the city competes with Singapore as the center of Southeast Asia.

In the area surrounding Bangkok, there are many water channels and rice fields, but they are not proving to be barriers to expansion of the city.

Besides, the city is supplied with power from North Bangkok Steam Plant (237.5 MW) and diesel power plants in its vicinity, and from distant places such as Bhumibol Hydroelectric Power Station (420 MW).

The population of Nakhon Ratchasima was approximately 42,000 in the census of 1960, but in 1963 it had increased to approximately 52,000 for a population growth rate of 24% in 3 years. This city is an important point on the highways and railraods connecting the North-eastern Region with Bangkok and is a collection point for the agricultural products of the Northeastern Region.

The city is mainly supplied with electric power by transmission line from Ubolratana Power Station (25 MW) and has a local diesel power plant as a supplement.

In the neighborhood of the project area there are a number of factories and mills. These plants are of relatively small scale, most of them being no more than cottage industries.

Near Sara Buri, there are factories for cement and cement products, brick and tile, and crushed stone and stone products. In the vicinity of Nakhon Nayok there are crushed stone and stone products factories and an ice manufacturing plant. Near Prachin Buri there are plants for crushed stone and stone products, and lumber and plywood. Limestone quarried at Prachin Buri is used as construction material.

There are a number of mineral resources in the vicinity of the project area, but the degree of development is low while the reserves are unknown. Graphite, copper and iron are produced near Sara Buri, while pagodite, soapstone and talc are produced near Nakhon Nayok. Near Prachin Buri, copper, gold and porcelain clay are produced.

The distance from Bangkok to Nakhon Nayok is connected by National Highway 305. This highway is an asphaltic concrete road and the distance from Bangkok to Nakhon Nayok is only approximately 100 km. Also, National Highway 33 connecting Sara Buri, Nakhon Nayok and Prachin Buri is an asphaltic concrete road.

The distance from Nakhon Nayok to Wang Ta Kai Botanical Garden and Nang Rong Waterfall near the entrance to the Khlong Tha Dan Basin is approximately 15 km, over which there is an asphaltic national highway approximately 4 m wide. Further, from Nakhon Nayok to Ban Tha Dan Village at the entrance to the Khlong Tha Dan Basin, there is an unpaved provincial road approximately 4 m wide. Therefore, it may be said that accessibility to the Khlong Tha Dan project area is very good.

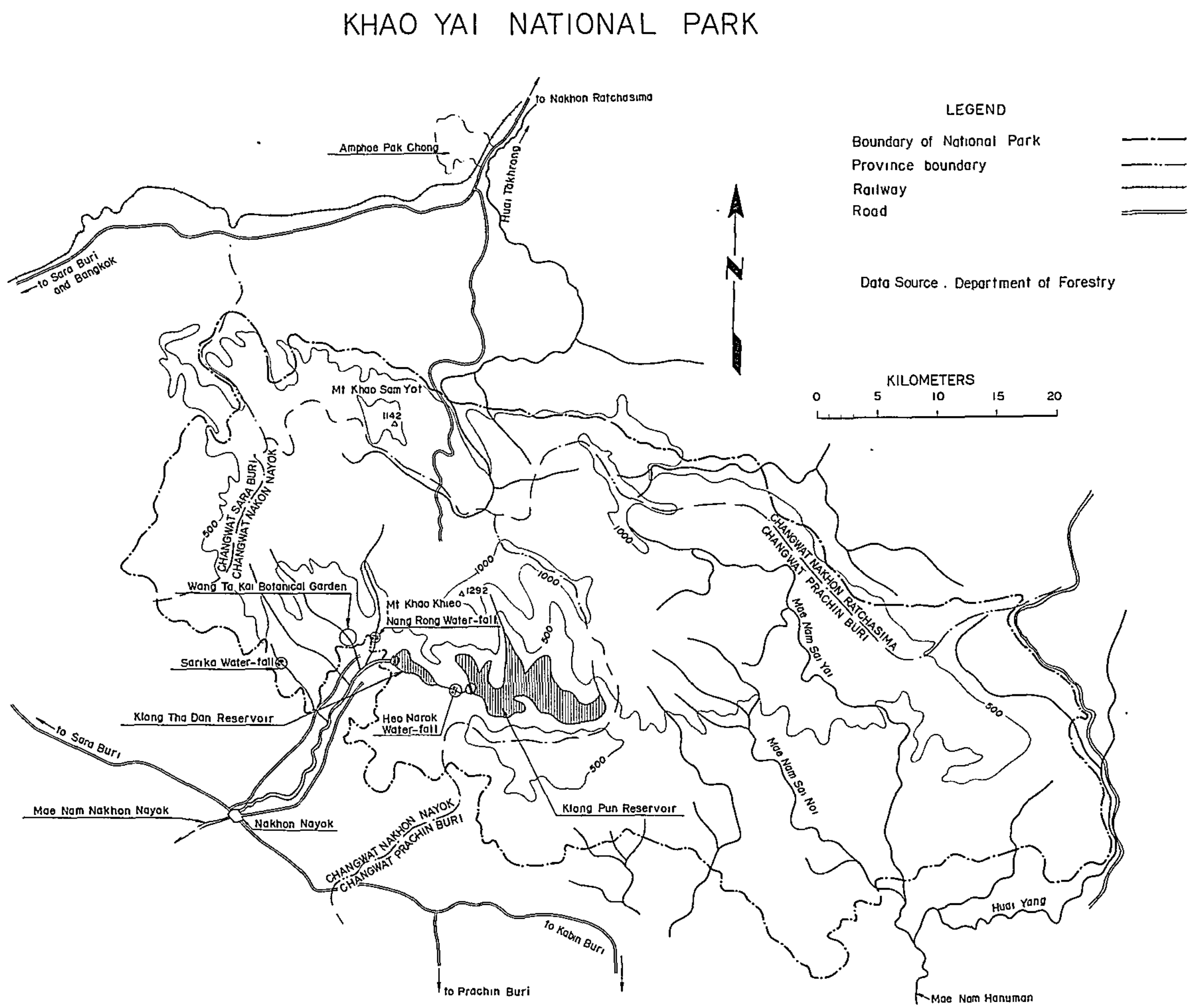


Fig 3-1 Khao Yai National Park

However, up to the present, there is no road beyond the entrance of the Khlong Tha Dan Basin to approach upstream points. The upstream area is covered with dense evergreen forests. Therefore, the only way of approaching upstream locations is to follow a wild elephant trail on foot.

In the downstream from the proposed Khlong Tha Dan Dam to National Highway 33, there are approximately 20,000 to 30,000 ha of arable land. This arable land adjoins the existing Nakhon Nayok Irrigation Project with National Highway 33 as the boundary line.

For the present, factories around the project area are not of large scale so that the major load center for the electric power from this Project would be Bangkok.

The area around Bangkok is rapidly becoming industrialized while the general demand for power in Bangkok is also increasing greatly.

3.2 Climate

According to data published by the United Nations*, the climatic zone of the project area is that of a "tropical wet and dry climate" and has the following features:

"Distinct dry season during winter (generally November – March) with at least one monthly rainfall, mean temperature of the coolest month above 18°C."

In general, there are three seasons in this climatic zone:

1. Hot season: Mid-February – Mid-May
2. Rainy season: Mid-May – Mid-October
3. Cool season: Mid-October – Mid-February

That there are three seasons is due to the influence of monsoons on this zone.

From mid-May until mid-October, the southwest monsoon blows in carrying moisture from the Indian Ocean to bring about the rainy season.

The rainfall is especially heavy in August and September.

From mid-October until mid-February the northeast monsoon blows down from the mainland of China and the Siberian area to produce the cool season during which there is Practically no rainfall.

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* "Atlas of Physical, Economic and Social Resources of the Lower Mekong Basin," September 1968, United Nations.

From mid-February to mid-May is a transition period in which the Pacific air mass moves to this zone from the east and southeast. Because of this the weather is hot and dry.

The climatological data for the project area are as shown in Table 3-1.

Table 3-1 Climatological Date of Khlong Tha Dan Project
(Data at Prachinburi) *

Month	Monthly Mean Temperature (°C)	Season
Jan.	27.1	Cool
Feb.	28.7	"
Mar.	30.1	Hot
Apr.	30.7	"
May	29.6	Rainy
June.	28.8	"
July.	28.4	"
Aug.	28.3	"
Sept.	28.0	"
Oct.	28.2	"
Nov.	27.8	Cool
Dec.	26.8	"
Average	28.5	

* Comprehensive Development Scheme, Nam Sai Yai Basin, OTCA, Government of Japan, Sep. 1968. p 42

3.3 Present Conditions of Electric Power Industries

All of the electric power industry of Thailand, except for small-scale private power companies, is operated by state enterprises. The administrative supervision of the Government over the electric power industry is shared by two government agencies, the Department of Public and Municipal Works of the Ministry of the Interior and the National Energy Authority under the Ministry of National Development, while as electric power industries, power generation and transmission are carried out by the Electricity Generating Authority of Thailand, and power distribution by the Metropolitan Electricity Authority and the Provincial Electricity Authority. The major authorities concerned with the electric power industry are described below.

National Energy Authority (NEA)

NEA comes under the jurisdiction of the Ministry of Development and carries out establishment and coordination of the overall power development program. At the same time, NEA constructs hydroelectric power stations already having completed Nam Pung Power Station (6 MW) in the Northeastern Region, while Lam Dom Noi Power Station (24 MW, ultimately 36 MW) and Mae Hong Son Power Station (1 MW) are now under construction. However, NEA does not operate power stations which have been completed, these being assigned to EGAT.

Besides the above, NEA from a national development standpoint, is engaged in surveys of lignite resources, planning of crude oil transportation by pipeline and of surveys for oil-well development in the Gulf of Thailand.

Electricity Generating Authority of Thailand (EGAT)

EGAT is an authority which was established newly in May 1969 through unification of the Yanhee Electricity Authority, the Northeast Electricity Aughority and the Lignite Authority which had existed up to that time. Through this unification, whatever had been operated independently up to that time, including power generating facilities and power transmission facilities, came to be operated as one, and an efficient management is looked forward to. The power produced is sold wholesale to MEA and PEA, but direct supply is also made to some of the larger consumers. (See Table 3-2)

Metropolitan Electricity Authority (MEA)

This is an authority which supplies electric power to the Greater Bangkok Area where approximately three-fourth of the entire power load of Thailand is concentrated. The electric power is purchased wholesale from EGAT at primary substations. MEA comes under the Ministry of the Interior.

Provincial Electricity Authority (PEA)

This is an authority for electric power distribution supplying all of Thailand other than the MEA supply area. The power distributed by PEA is mainly purchased wholesale from EGAT, but at areas isolated from the EGAT system, PEA is carring out power generation with diesel engines. PEA comes under the Ministry of the Interior.

Table 3-2 Generating Facilities of EGAT

		Installed Capacity (MW)		
		Total	Hydro	Thermal
1.	Central and North Region			
	Bhumibol Hydro	420	420	
	North Bangkok Thermal	237.5		237.5
	South Bangkok	200		200
	Mae Moh Thermal	12.5	12.5	
	Samsen old Thermal	17		17
	Gas Turbines	60		60
	Diesels	27.4		27.4
	Total	974.4	420	554.4
2.	Northeast Region			
	Ubol Ratana Hydro	25	25	
	Nam Pung Hydro	6.3	6.3	
	Nakhon Ratchasima Gas Turbine	15		15
	Udon Thani Gas Turbine	15		15
	South Ratchasima Diesel	4		4
	Total	65.3	31.3	34

3.	South Region			
	Krabi Thermal	60		60
	Phuket Diesel	10.6		10.6
	Total	70.6		70.6
4.	Grand Total	1,110.3	451.3	659.0

Royal Irrigation Department (RID)

RID has a long history of water resources development planning and execution. The well-known Bhumibol Project was completed by this department. In Thailand, there are many cases when water resources are planned to be developed for multiple purposes.such as hydroelectric power generation and irrigation or flood control. RID comes under the Ministry of National Development.

The power system of Thailand, since the start of EGAT in May 1969, has been operated with the Central, Northern and Northeastern regions as a single system. Through this unification, except for the Southern Region which because of geographically isolation will not be interconnected with the Central System until a considerable time later, all of Thailand has come to be interconnected.

Since approximately 75% of the power demand of entire Thailand is concentrated in the metropolitan area with Bangkok as a center, the power system takes on a form to correspond to this situation. In other words, the skeleton of the power transmission system of Thailand is formed by the trunk transmission lines connecting the hydroelectric power resources area in the north and Bangkok, and the perimeter transmission line connecting the thermal power stations of large-capacity around Bangkok. The maximum voltage of the system is 230 kV. In the Northeastern Region, a 115-kV transmission line serves as the trunk line.

Year	Total Generation (million kWh)	Increase (%)
1959	498	-
1960	567	13.8

1961	680	20.1
1962	776	14.0
1963	913	17.7
1964	1,092	19.6
1965	1,406	28.7
1966	1,854	31.9
1967	2,414	30.2
1968	3,062	26.8
1969	3,727	21.7
	Ten-Year Average	22.3

The growth in power demand in recent years has been truly amazing. Particularly, during the three years of 1965, 1966 and 1967, the growth rate over each preceding year was around 30% to double the demand in 3 years. This is such a high rate that it may be said to be abnormal considering that in the developed nations of Europe and America doubling of demand is said to take a period of 10 years (7% in annual growth rate). In order to cope with this sharp load increase, EGAT has hurriedly installed a total of 150 MW in gas turbines which have short delivery times.

The reason conceivable for such sharp increases in demand is the stable political situation under which industrialization policies are effectively being carried out, resulting in vigorous economic activity. In the first half, 1961 – 1963, of the First Five-Year Program for Economic and Social Development, a growth rate in GNP of 6% was achieved, which exceeded the 5% targeted, and in the Second Five-Year Program a target growth rate of 8.5% has been established.

However, even the Thai economy which had boasted such a high growth, has slowed down so far as seen from power demand with 1967 as the borderline, and in 1968 the growth rate in the demand was 26.8% and in 1969 it was down to 21.7%. If the statistics for 1970 had been available, this trend could have been confirmed more distinctly, but this was not possible. However, according to presumptive information, it is estimated that the rate was somewhat below 20% in 1970. Even then, this figure itself is still high, being two to three times that of ordinary countries.

In this way, the growth in power demand in Thiland hereafter may not be explosive, but still a high level of more than 10% should continue for a fairly long period.

This is because the population increase is still continuing to indicate a high rate of more than 3%, the energy production per capita was 90 kWh even as late as 1968, extremely low as seen from the world level, while only 17% of the entire population was being supplied with electricity even in 1969. Therefore, if consolidation of the power distribution network and lowering of electricity rates are carried out steadily, there is adequate room for demand to increase. With the rise in living standards centered in the cities, energy consumption has increased at a fairly high rate (in the MEA area, between 1964 and 1968, the consumption for residential use per customer increased at an average annual growth rate of 13%).

The power generating facilities of Thailand are as indicated in the table 3-2, the installed capacity being 451 MW hydro, 659 MW thermal for a total of 1,110 MW.

Of hydroelectric facilities, the main is Bhumibol Power Station, 420 MW (70 MW x 6 units), while North Bangkok Thermal, 237.5 MW (75 MW x 2 + 87.5 MW x 1), and South Bangkok Thermal are the major thermal power plants. Samsen Thermal Power Station (17 MW) has become fairly aged. As for diesel generating facilities, an overwhelming number is of small scale of about several hundred kW.

Of the power stations presently under construction, those which are hydro are Lam Dom Noi (24 MW, to be completed end of 1971), Nam Phrom (40 MW, to be completed 1972) and Sirikit (First Stage, 250 MW, to be completed 1973) for a total of 314 MW.

As for thermal plants, in succession to the No. 1 Unit at South Bangkok, the No. 2 Unit, 200 MW, is under construction and is scheduled to be added to the power system in 1972. Further, with respect to the No. 3 Unit, 300 MW, the equipment has already been ordered and completion of this unit is planned to be in 1974. This power station, including a fourth unit, 300 MW, is planned to ultimately have an output of 1,000 MW.

In step with development of these power sources, the power system has been gradually expanded, and with completion of Lam Don Noi and Nam Phrom power stations, it is also planned for the trunkline network for the Northeastern Region consisting of 115-kV transmission lines to be completed. Also, with construction of South Bangkok Thermal Power

Station, the outer loop line surrounding the Bangkok-Thon Buri area has been completed to improve greatly the reliability of supply to the capital area. In the provinces, the construction of 69-kV and 22-kV trunk distribution lines is progressing and supply is being made to increased new customers.

At the strong behest of the Thai Government, the electricity rates in Thailand have been lowered every two years, which has stimulated demand and has been one of causes of the abnormal growth rate.

The electricity rates differ according to area in the rates of MEA applied to the capital area and those of PEA to the other areas. The PEA rates further differ again according to area with a large spread between the rates depending on whether the source of power supply is diesel or purchase from EGAT. These rates are 80 – 100% higher than those of MEA.

In the Central Region, the wholesale rates of EGAT to MEA and PEA differ greatly according to load power factor. At power factor of 70% the rate is 0.285 Baht/kWh. Against this, the electricity rates for large consumers of MEA and PEA are 0.30 Baht/kWh and 0.357 Baht/kWh respectively (power factor 70%). On the one hand, the electricity rate for residential use in the case of MEA, calculated on a trial basis assuming consumption of 100 kWh per month, would amount to 3.31 cents per kWh and is fairly cheap, but this is 5.61 cent/kWh in the case of PEA. This rate in areas supplied by diesel becomes 7.02 cent and is extremely high.

The Thai Government, recognizing the importance of electricity rates on the people's livelihood and economic activity, has acted positively for reduction in these rates. The table below shows the relation between reduction in electricity rate and increase in consumption per customer.

Year	Energy Consumption per Customer (kWh)	Average Annual Revenue per kWh Sold ($)
1964	1,455	0.76
1965	1,809	0.66
1966	2,261	0.61
1967	2,762	0.57
1968	3,207	0.53
1969	3,560	0.53

The electricity authorities, MEA, PEA and EGAT have coped with the reductions of rate through rationalization of management, modernization of facilities and increase in quantities of energy sold, but as can be seen in the table above, the reductions in the rates have become gradually smaller, indicating that the limit in reductions through such measures is being approached.

CHAPTER 4

PROBLEMS AND NEEDS

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CHAPTER 4. PROBLEMS AND NEEDS

It would be needless to say that the electric power is one of factors essential to economic development of a nation. This electric power must be abundant and cheap, and the supply thereof must be dependable.

The Royal Thai Government, because of this necessity, has been exerting itself with respect to the electric power development and the electric power supply. However, because the economic development has been very rapid, power demand has exceeded supply until recently. It is only very recent that it has become possible to supply the reliable electric power with reasonable cost in comparatively sufficient quantity to the capital city of Bangkok. Since the economy of Thailand centered in Bangkok would still continue to grow, the necessity for the electric power development is a current problem which will persist in the future.

The Thai Government, because of this urgent need for the electric power development, is planning to develop, besides hydroelectric power plants, exclusively oil-burning thermal power plants and a nuclear power plant in the area surrounding Bangkok. As in many developed countries, these power plants in an interconnected power system would supply base loads, while the hydroelectric power plants would supply peak loads. In other words, a necessity would arise for hydroelectric power development projects to be planned to serve as peak load stations. Further, thermal power plants and nuclear power plants, for the reason of economy in their operation, present the problem of surplus power being produced at midnight. The necessity should arise in the future of planning the construction of hydroelectric power stations for pumped-storage power stations which would utilize this surplus power and could be operated efficiently as peak load stations.

The Khlong Tha Dan Project area, as indicated in the Key and Location Map, is close to the capital city, Bangkok, and a major city of the Northeastern Region, Nakhon Ratchasima (Khorat), so that it is located at a site well suited for a peak load station and should be able to meet at least part of the necessity for such stations.

4.1 Load Forecast

It has been considered to be one of the most difficult tasks to accurately make a load forecast for the electric power system of Thailand. This is because the growth rates of load more than 20% have unexpectedly continued for a long time. No one had been able to anticipate such high rates as much as 30% before they actually happened, and load forecasts made in the past have always been far lower than actual.

In 1966, the Thailand Electric Power Survey Team, sponsored by the USOM, carried out an investigation of the electric power industry of Thailand and submitted a report named "Moulton Report". The load forecast made in this survey was based on the "philosophy of plentifulness" and was of a considerably larger forecast than past ones. The EGAT has established its own plan of power development mostly on the basis of the USOM forecast.

On the one hand, the Feasibility Report on the Quae Yai No. 1 Project was submitted to the EGAT by the EPDC in 1968. In the report, forecast was made based on the correlation between the GNP per capita and the consumption per capita. The result was slightly lower than the one forecasted by USOM.

In October of 1969 a study team of the USOM headed by Dr. H.F. Jones prepared "Thailand Electric Power Load Forecast 1970 – 1990", with the cooperation of Thai government authorities concerned. This is the latest forecast and is known as the "Jones Report."

The present study team has considered the load forecast of Thailand electric power on the basis of the Jones Report as described below.

The significance of the GNP-kWh correlation curve or the so-called world curve is that in any country in the world — even with differences in geographical, social, economic and cultural conditions — there is a constant relationship between GNP and kWh as indicated by the world curve (with of course a fair amount of allowance between upper and lower limits) (See Fig. 4-1). There is admittedly the appearance of change in GNP-kWh in Thailand which was much more rapid than that of the world curve, but it is possible to assume that in the future this change will become more moderate to be in line with the world curve. There has actually been a slow-down in growth of demand and it seems not to be expected for a growth in excess of 30% in 1970 to be attained as forecast in the Jones Report, while in regard to reductions in electricity rates, the percentage of reduction has become gradually smaller and it is thought the effect of stimulating demand will not be as great as before.

Our load forecast was made from this viewpoint with the curve considered to become parallel with the world curve from 1970 and thereafter for a more gradual increase in demand than previously seen. According to such an assumption, from 1970 for two or three years while the transition is being made from a sharp rise to a more gentle change, it is expected there will be some error, but it is considered that for the years with which the Khlong Tha Dan Project will be concerned a reasonable forecast will be provided.

In regard to growth rates in GNP and population, the conditions were taken to be the same as in the Jones Report. (See Appendix A-1). The results for forecasts are given below.

	1975	1980	1990	Units : Billions of kWh
GNP I/P_1	8.23	13.1	28.2	
GNP I/P_2	8.35	13.6	31.3	
GNP II/P_1	8.7	15.4	45.1	
GNP II/P_2	8.79	15.9	49.3	
GNP III/P_1	8.67	15.59	53.3	
GNP III/P_2	9.8	18.3	58.0	

Of the results shown above, GNP II/P_2, indicating a median value and considered to give the most reasonable growth rates for GNP and population, was adopted as the most probable case. The comparisons with past forecasts are given in Fig. 4-2. As can be seen in the figure, the results of present forecast are naturally almost the same as those of USOM or EGAT until around the year 1980.

In this Report, the establishment of a development plan and consideration of the timing of development will be carried out based on this load forecast, but the forecast results of the Jones Report will be used for reference as the upper limit of possibility. As seen in Fig. 4-2, there are differences with the forecast of the Jones Report of 3.5 years in 1975 and approximately 4 years in 1978 – 1985. In other words, when development becomes necessary in 1980 based on the present study team's forecast, the necessity would arise prior to this in 1976 according to the forecast of the Jones Report.

The results of the present forecast have been plotted on the trend curve of the past growth in electric energy production and the per capita electric energy production curve for checking (See Fig. A-1-2 and Fig. A-1-3 of Appendix A-1). As seen from the figures, it can be said the present forecast looks to a growth rate roughly similar to that in the stable development period from 1954 to 1964.

Fig 4-1 Average Relationship of GDP/Capita to kWh/Capita (World Curve) (1966 Data)

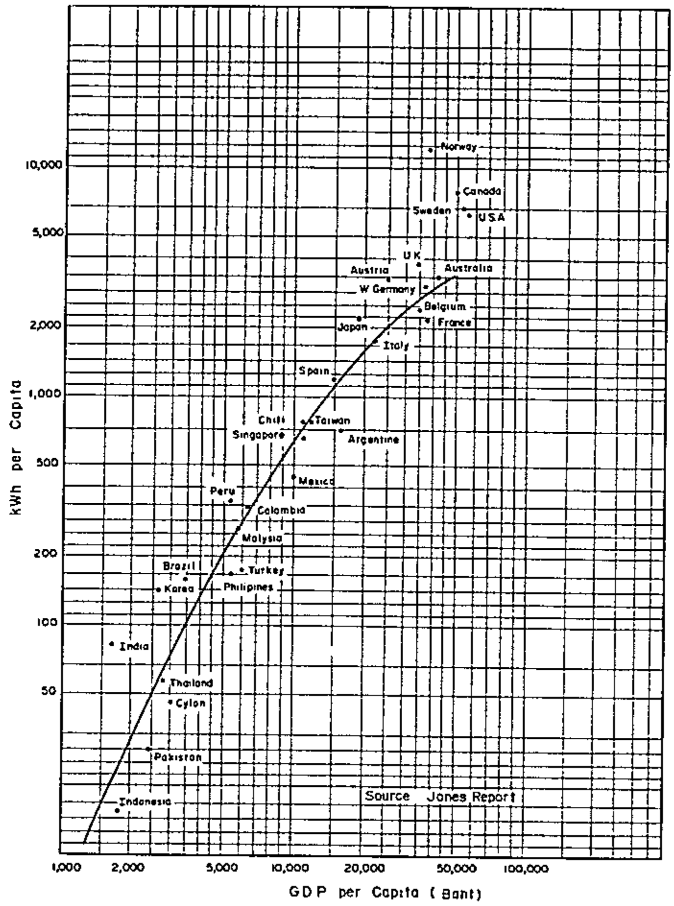
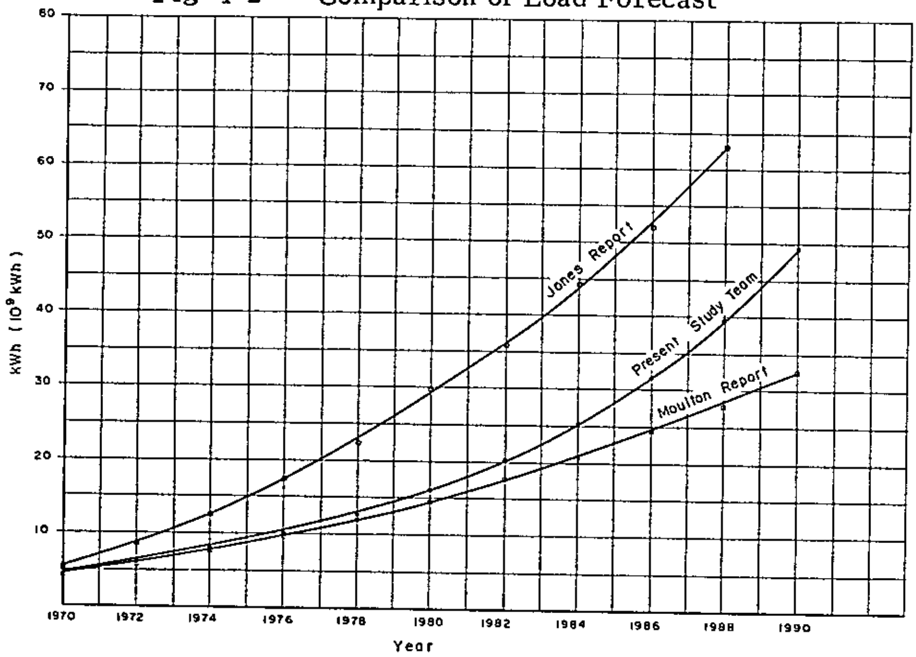


Fig 4-2 Comparison of Load Forecast



In any event, and as has also been stated in the Jones Report, it is of most importance for the results of load forecast to be reviewed yearly with changes in the conditions assumed and corrections made for a more accurate forecast.

4.2 Load Curve

Fig. 4-3 indicates a typical (max.) daily load curve for the Central and North Region of EGAT's system. In the Northeast Region and in Southern areas, the peak in the evening at lighting-up time is even more prominent than in the Central and North Region, but since the loads in these areas are only about 5% of that of Central and North Region, the latter is considered to be representative. For the period from 1966 to 1969, there was no yearly change in the daily load curve with the daily load factor being 72%. In studying the daily load curve, the following can be pointed out.

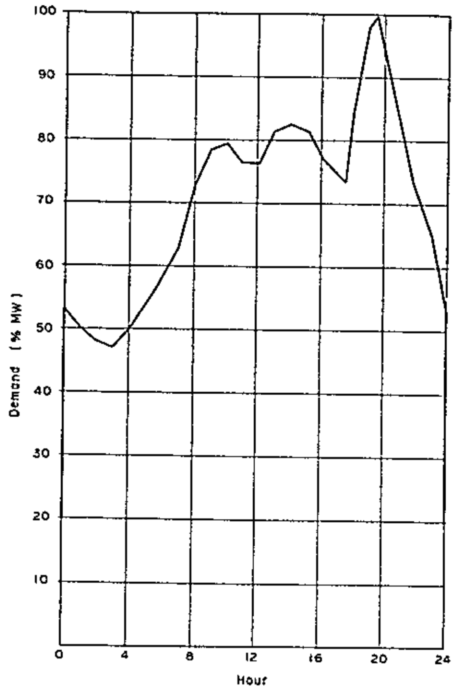


Fig 4-3 Typical Daily Load Curve

(1) There are 3 peaks, that is, in the moring, in the afternoon and at lighting-up time. The peak in the evening centered around 6:00 p.m. is exceedingly more prominent than the former two. The duration period of this peak is approximately 3 to 4 hours.

(2) The morning peak occurs around 10:00 a.m. but the rise is very gentle. The afternoon peak comes around 2:00 p.m. after the lunch hour and is slightly larger than the norming peak.

(3) The minimum load is at about 3:00 a.m. in the morning and it is as large as 50% of the daily peak.

The load curve is a reflected figure of national living and industrial activity, but will not to be considerd in a fixed manner. The power consumption in the daytime will increase with the progress in industrialization, and the daytime peak will become larger with the increase in loads for air-conditioning. It is conceivable for this reason that the load curve will be changing. However, the load curve would not be changed in the next 10 years, if consideration is given to the present conditions in Thailand where there are still many areas which have not been electrified. In fact, during the period from 1966 to 1969, there was an increase in power demand recorded which had never arisen in the past, but so far as seen by the load curves recorded, there is no prominent change. Therefore, the considerations made in this Report will be based on the existing load curve up to 1969.

4.3 Power Supply for Peak Load

In the daily load curve of Fig. 4-3, it is indicated that the morning peak is brought about in a gradual manner. In other words, from the minimum load at 3:00 a.m. the first peak is reached in approximately 10:00 a.m. and this load can be adequately met even with thermal power stations. The second peak is slightly larger than the peak in the morning, but this also is not accompanied by a sudden change. However, the lighting-up peak in the evening starting from around 5:30 p.m. reaches the peak in one to one and half hours (namely 6:30 - 7:00 p.m.) and subsequently declines rapidly in the same manner and results in a change corresponding to approximately 20% of the system load in a period of about 3 to 4 hours. Therefore, against such a sharp rise and fall in the peak, it is thought the most appropriate method will be to supply power from peak power sources mainly comprised of hydro.

In other words, the loading characteristics of a thermal unit to adapt to the load is extremely poor due to limitations derived from thermal stress, and the sudden changes in load are underirable. As an example, with a 200-MW class thermal unit, 2 hours is required to go from parallel to full-load operation and more time is required with the most modern equipment which are of large unit capacities. Nuclear power generation is more or less the same as thermal power in this respect. Also, such load variation will naturally lower operating efficiency. On the other hand, hydroelectric units have superior adaptabilities through which full-load output can be provided in 2 to 3 minutes, and therefore are suited to being operated at peak hours. It may thus be said that a combination of hydro and thermal, with the base portion of the load carried by new, large-capacity thermal power stations and the peaking portion by hydro, would comprise the best supply method matching the conditions of the momentary variation in load.

As features required of peak power supply, besides the abovementioned superior adaptability to loads, the installation cost should be cheap because of the short operating times, and there should also be a possibility for large scale to be achieved as the growth rate of the demand is very high.

Generally speaking, there are the following four sources conceivable as peak supply capacity.

1. Hydro

2. Gas turbine

3. Thermal

4. Pumped storage

Ordinarily, hydro power stations are superior in their advantage of fast-loading characteristics, but the construction cost per kW is generally more expensive than thermal power plant. Facilities in Thailand which can be considered as exclusively peak hydro are the No. 7 and No. 8 Units (total 140 MW) of Bhumibol Power Station and the No. 4 Unit (125 MW) of Sirikit Power Station. The both power plants have dams which are already completed and thus exceedingly cheap peak supply could be obtained, because the additional construction cost would be only the equipment costs such as for turbines and generators ($20-30 kW). But these are special cases and are not general in nature. When there does arise a necessity for peak supply capacity, it is thought these would be the first to be developed.

Since gas turbines are easy to start and stop, are of compact design and have short delivery times, there are already ten 15-MW units installed in Thailand, but there are drawbacks such as the unit capacities cannot be made very big and fuel costs are high because of low efficiencies, so that it is thought this type would be limited to use in emergencies. According to the experience in Thailand the construction cost of this type is $120 – 160 per kW.

Using old thermal plants of poor efficiency for peak supply is a common practice in many countries, and in EGAT, Samsen Thermal Power Station, 17 MW, has been used in this manner, but because of its aged condition it is assumed this station will be retired at a time when a surplus is available in supply capacity. It is thought subsequently, that, thermal units of old age and small capacities may be made to fulfill this role in order, but because of the fact that they are thermal power plants, they would naturally be inferior to hydro in adaptability to loads and quickness in starting and stopping, and are not suitable for peak demand of the type at the evening lighting-up time in Thailand. Thus, these units should do no more than carrying intermediate loads which cannot fully be covered by hydro.

Pumped-storage power stations are ideal as peak supply capacity and inherit the good loading characteristics of hydro. Such plants absorb the surplus power of thermal and nuclear power stations produced in the middle of the night for pump-up storage and make possible high-efficiency operation of these large-capacity thermal units. The stored water is released for power generation at such times as the evening lighting-up time of strong peak demand, but this is looked upon not as an energy producer but as a kind of value converter producing power at peak hours using the cheap power of the middle of the night. In principle, the water needs only to go back and forth between the upper reservoir and the lower reservoir so that no discharge is required throughout the year and only waters enough to first fill the reservoir is necessary. Geographical limitations are thus fewer and this type may be said to be hydroelectric power generation free of the limitations of river runoffs. Therefore, large capacity is readily produced, and since the cost is lowered with larger capacity, this is most suited for coping with sudden increase in demand. In recent years there has been marked technical progress in regard to reversible pump-turbine in Japan and the U.S.A. with applicable heads having been increased to around 500 m.

Since pumped-storage stations pump up water and generate power purchasing the midnight surplus power of new thermal power stations, the unit cost of the energy produced will vary greatly depending on the unit price of the energy purchased, the overall efficiency of pumped-storage power generation and the annual generating hours.

The measure of construction cost of pumped-storage power generation is considered to be around $130 – 110 per kW.

From the above considerations, it could be judged that pumped-storage power generation will be the most superior method of supplying peak demand in the future power system of Thailand.

Recently, there has been a worldwide trend for the price of petroleum to be increased. The rise in petroleum prices will naturally raise the generating costs of thermal power stations, which in turn will impair the economics of pumped-storage power generation. However, if the sharp rises in fuel costs of fossil-fuel thermal power stations continue over a long period of time, relatively, the transfer to nuclear power generation will be spurred on. The fuel cost of nuclear power generation is estimated to be approximately one-half of fossil-fuel thermal, and in the event of a switch to nuclear power, pumped-storage power generation will become of even greater advantage and economy.

According to the load forecast of Chapter 4-1, it is estimated that the maximum load will be 3,000 MW in 1980. If it is assumed there will be no great change in the form of the load curve from the present, there should be approximately 600 MW of peak supply capacity necessary for the economical operation of the power system. Further, in 1985, there should be a requirement to expand this capacity to 1,000 MW.

As for the capacity exclusively for peak supply, there will be the No. 7 and No. 8 Units, 140 MW, of Bhumibol Power Station, the No. 4 Unit, 125 MW, of Sirikit Power Station and the Second Stage, 360 MW, of Quae Yai No. 1 Power Station for a total of 625 MW. Since these could all be completed at the cost only of additional equipment or power stations, it is consedered these will naturally be developed with priority over other peak supply capacities. Therefore, such peak supply capacities including pumped storage such as the Khlong Tha Dan Project will be in operation later on, namely from 1980 or after.

4.4 Power Development Scheme and KW Balance

The peak demand was determined assuming annual load factor from the required energy production calculated in Chapter 4-1. It was assumed from the past performances that annual load factors would be 57.1% in 1975, 59.6% in 1980 and 62.5% in 1990. The supply capacity required by the power system was assumed to possess a reserve capacity of 10% added to peak demand in order to cope with errors in load forecast, drought and faults (see Tables A-1-1, 2 of Appendix A-1). In order to supply such energy and peak kW required, it is necessary for development schemes to be established and development made successively based on such plans. In general, development of power sources, particularly hydroelectric power sources, require long periods of time from several years to about 10 years, and therefore, the projects to be added to the power system by the latter part of the 1970s have already to take shape considerably, with work on some projects already started. In other words, power development schemes up to about 1976-1978 cannot but be developed according to established policy, and in the present Report the balance of demand and supply was examined based on the power development schemes of EGAT and NEA.

A tentative power development scheme is indicated in Table A-1-3 of appendix A-1.

The major projects to be added to the power system by 1978 would be in the case of hydro, Sirikit No. 1, No. 2 and No. 3 (375 MW), Quae Yai No. 1 (No. 1, No. 2, No. 3 — 360 MW), Sai Yai (70 MW), and in the case of thermal, No. 2 Unit, 200 MW, and No. 3 and No. 4 Units, each 300 MW, of South Bangkok, while the first nuclear power station in Thailand, a 500-MW unit, is scheduled for start-up in 1978. In the event that for various reasons the nuclear power station will be delayed beyond this time, it is planned, instead, to install a thermal unit of the same capacity so that no change will occur in the power development scheme.

Demand and Supply Balance

The electric energy supplied for the energy requirement was calculated based on firm energy in the case of hydroelectric power stations, and 80-70% annual load factor in the case of thermal power stations. Regarding supply capacity, the dependable peak capacity was used for hydro and installed capacity for thermal.

The results of kW and kWh balance are as shown in Tables A-1-1, 2 of appendix A-1 indicating that up to 1978 the balance of demand and supply can be maintained through the present power development scheme. Therefore, it is estimated that the time for addition of new power sources including the Khlong Tha Dan Project will be around the year 1980. On the one hand, if based on the forecast of the Jones Report, this would be in 1976.

Further, in order to study the role to be played by hydroelectric power stations within the system and the necessity for peak supply capacity, the kW balances diagrams were prepared based on daily load curves for the years of 1978 and 1980 (See Fig. 4-4, 4-5).

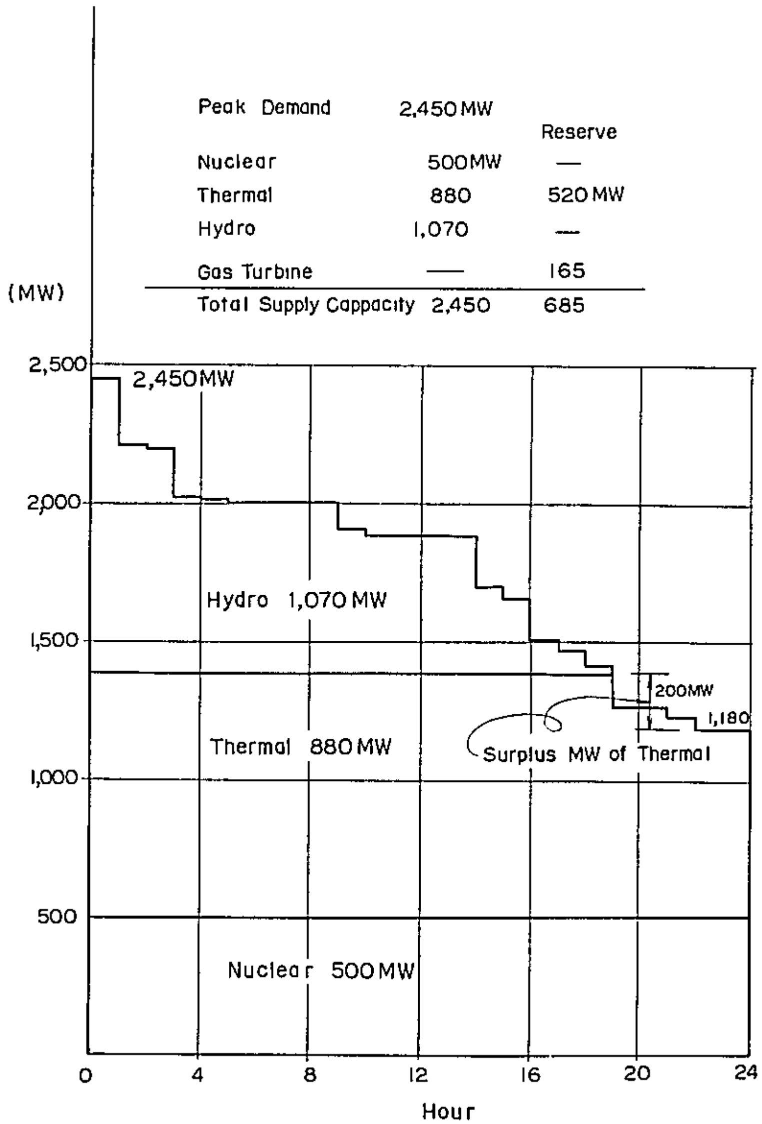
In 1978, 500 MW of nuclear power would already be added and operated to carry base load, but the midnight surplus of thermal power would be 180 MW x 5 hours which would be inadequate as resources for pumped-storage power generation of about 400 MW.

By 1980, the load would have been increased and the midnight surplus of thermal power would become fairly large. Therefore, the midnight surplus of thermal power would be about 440 MW x 5 hours. It is thus seen that power for large-capacity pumped storage can be secured from 1980 and later.

From the above, it may be said the time for development of the Khlong Tha Dan Project will be in the latter half of the 1970s.

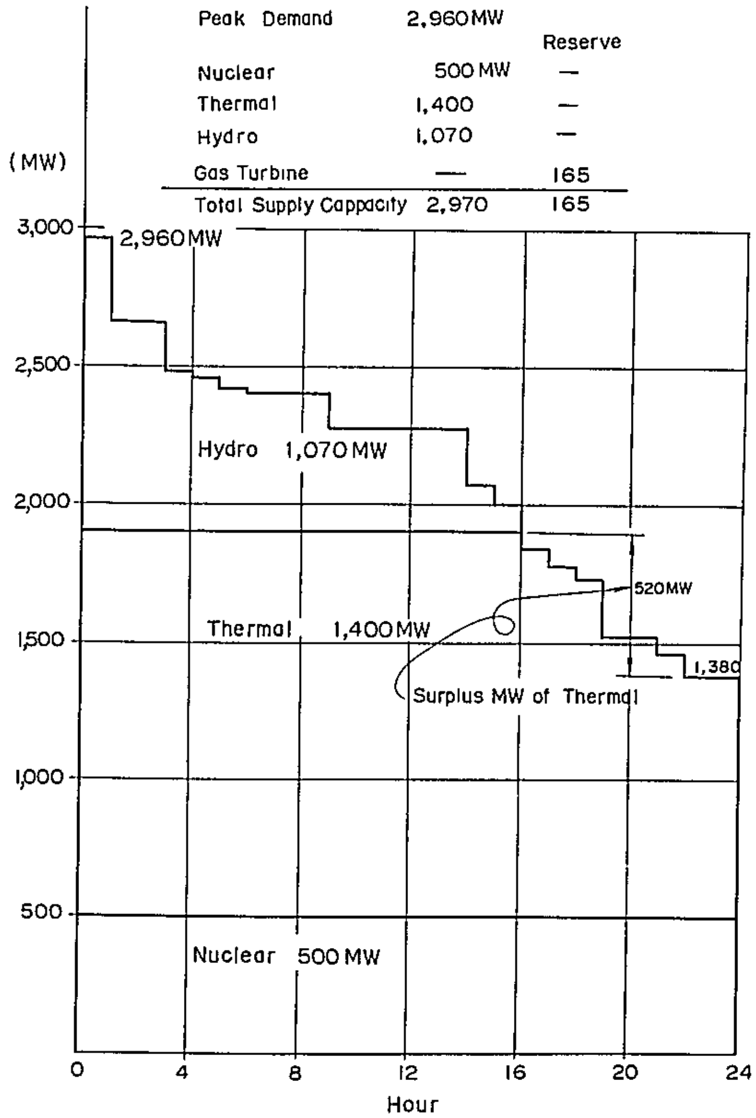
Further, conventional hydroelectric power generation of superior economics will also have the merits of effective utilization of natural resources, expediting of regional development, saving of foreign currency to be paid otherwise for fuel, and therefore, it is considered this should be developed in advance of thermal power.

Fig 4-4 Supply and Demand Balance in 1978



		Reserve
Peak Demand	2,450 MW	
Nuclear	500MW	—
Thermal	880	520 MW
Hydro	1,070	—
Gas Turbine	—	165
Total Supply Cappacity	2,450	685

Fig 4-5 Supply and Demand Balance in 1980



		Reserve
Peak Demand	2,960MW	
Nuclear	500 MW	—
Thermal	1,400	—
Hydro	1,070	—
Gas Turbine	—	165
Total Supply Cappacity	2,970	165

CHAPTER 5

HYDROLOGY AND GEOLOGY

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CHAPTER 5. HYDROLOGY AND GEOLOGY

5.1 Hydrology

The site planned for the Khlong Pun Dam is immediately upstream of Heo Narok Water Falls in the Khlong Tha Dan River and has a catchment area of 152.7 sq.km. The catchment belongs to a heavy rainfall area in Thailand with the annual amount being as much as 2,800 mm to 4,000 mm. The greater part of this rainfall is produced in the rainy season, which is hydrologically the six-month period from May through October and is concentrated especially in the months of July, August and September.

In contrast, during the dry season (cool season and hot season) comprised of the other 6 months, there is almost no rainfall. Because of this, there is extreme difference in the river discharge between rainy season and dry season with the discharge being large in the rainy season, while in the 6-month dry season from November through April the discharge is very small.

The catchment area, the locations of water gaging stations and meteorological observation stations in the surrounding area, are as shown in Fig. 5-1.

Also, the periods, for which records of runoff and precipitation at these stations exist, are as shown in Tables 5-1 and 5-2.

Although Nakhon Nayok Observation Station is outside of the catchment area of the Khlong Tha Dan Project, there are records of daily precipitation over a period of 19 years and it is possible to use these data in estimating calculations necessary for studying the power development scheme.

Within the catchment area, there is only the one gaging station of Ban Khlong Si Sook. The runoff records are for the 4-year 9-month period from May 1965 to December 1969.

The runoff at the proposed damsite, by using the correlation between the abovementioned runoff records of gaging stations and precipitation records of precipitation observation stations, can be determined with a fair degree of reliability for planning of the hydroelectric power development.

The meteorological data regarding evaporation are also used for determination of the evaporation from the reservoir surface.

The drainage area of the Khlong Tha Dan Project was determined based on a 1/50,000 scale map issued by the Department of Royal Thai Survey. According to this, the catchment is

Table 5-1. Existing Precipitation Data

Station	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70
Ban Klong Si Sook																				
Wang Heo																				
Ban Sapanhin													July							
Prachin Buri																				
Nakhon Nayok																				

Table 5-2. Existing Runoff Data

Station	River	C.A (KM²)	Latitude	Longitude	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70
Ban Khlong Si Sook	Khlong Tha Dan	196	14°18.4' N	101°19.7' E					Apr						
Wang Heo	Nam Sai Yai	314	14°17.5' N	101°41.9' E											
Ban Sapanhin	Nam Sai Yai	636	14° 08' N	101°44' E											
Khao Yai	Lam Ta Kong	60.7	14°26.4' N	101°22.2' E											

Table 5-3. Existing Evaporation Data

Station	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70
Ban Khlong Si Sook																				

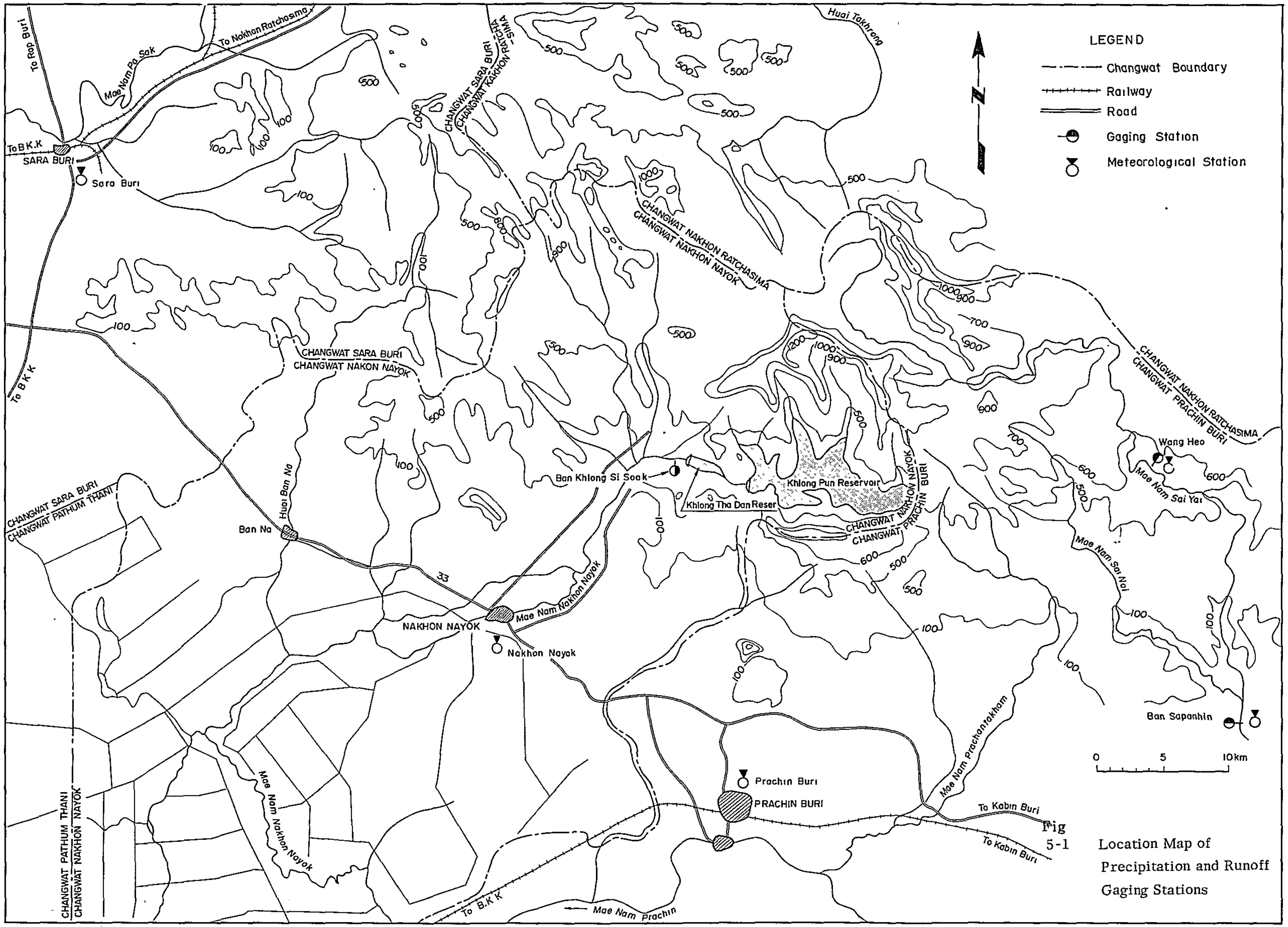


Fig 5-1 Location Map of Precipitation and Runoff Gaging Stations

152.7 sq.km at the proposed Khlong Pun damsite and 169.1 sq.km at the proposed Khlong Tha Dan damsite. Should the runoff of the two adjacent rivers Huai Nang Rong and Huai Som Phung Yai be introduced to the Khlong Pun site, the comined drainage area of the two rivers would be 140.1 sq.km (see Fig. 5-1).

The annual precipitations in the project area for the 19 years from 1952 through 1970 are indicated in Fig. 5-2.

According to this, it is seen that there is a considerable variation in precipitation by year, which, expressed in another way, means there will be a large variation in runoff depending for the study of power.

Therefore, in order to effectively use the river water, it is necessary to carry over the water of wet years to dry years. For this purpose, a fairly large reservoir would be necessary for this Project.

The variation in precipitation by month is shown in Fig. 5-3.

The correlation between cumulative runoff at Ban Khlong Si Sook and the cumulative precipitation at Nakhon Nayok for the period from 1966 through 1969 is indicated in Fig. 5-4. This period corresponds to the period in which observation records are available at the observation stations of both Ban Khlong Si Sook and Nakhon Nayok.

Based on this correlation between precipitation and runoff, the runoff at Ban Khlong Si Sook during the period from 1952 through 1970 was estimated through calculations. The relationship between the estimated runoff and the runoff measured at Ban Khlong Si Sook is indicated in Fig. 5-5.

On checking the results it is indicated that the runoff calculated from the correlation between precipitation and runoff and the runoff observed at Ban Khlong Si Sook are slightly close to each other. With this degree of approximation it is thought permissible to use the runoff calculated from the correlation between precipitation and runoff for the study of power development scheme. Therefore, it was decided to use the runoffs calculated from the correlations between precipitation and runoff from January 1952 through April 1965 and from January through December 1970. Also, for May 1965 through December 1969, it was decided to use the runoff measured at Ban Khlong Si Sook. These runoffs are given in Table 5-4.

The runoff at the proposed Khlong Pun damsite can be determined from 1961 to 1970 by using the ratio of drainage area of Ban Khlong Si Sook and the proposed damsite indicated in Table 5-5.

Fig 5-2 Annual Precipitation at Prachinburi, Nakhon Nayok and Ban Khlong Si Sook G.S

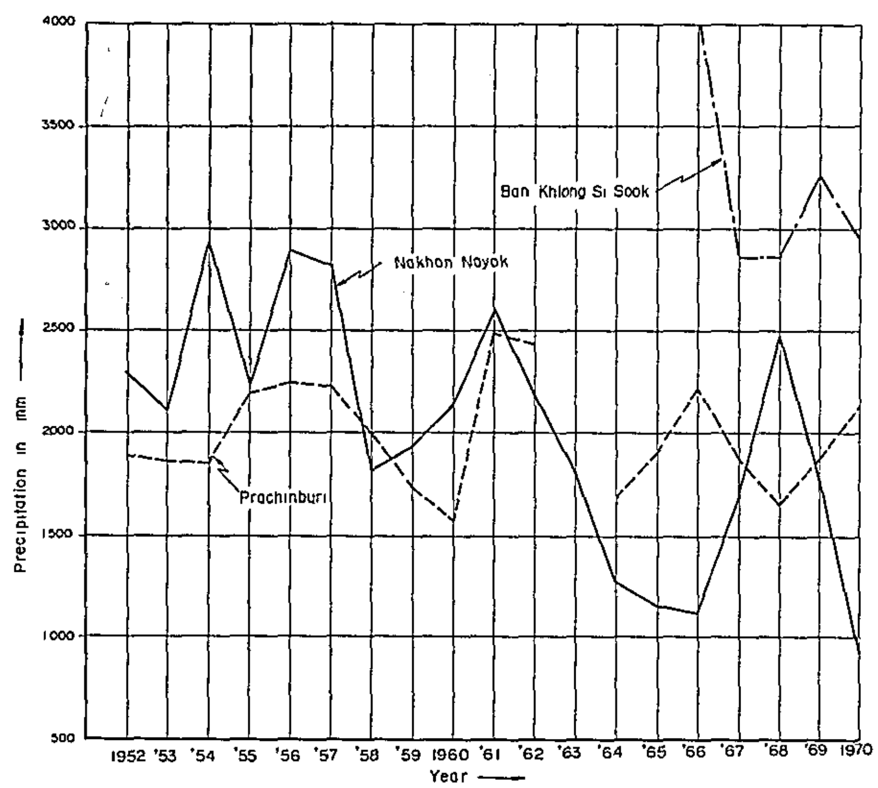


Fig 5-3 Monthly Precipitation at Nakhon Nayok and Ban Khlong Si Sook G.S

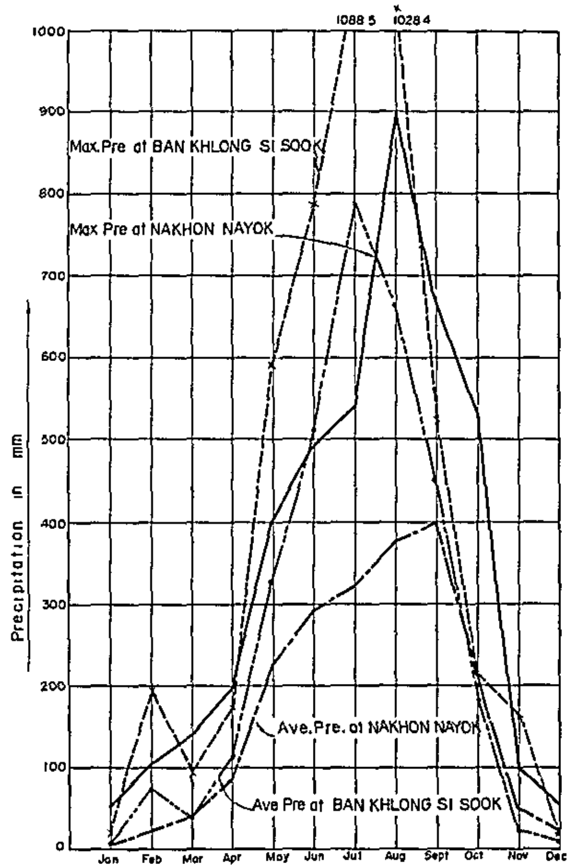


Fig 5-4 Correlation between Runoff and Precipitation

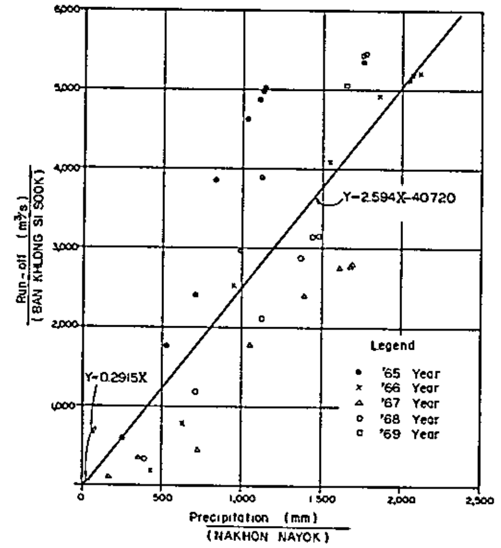


Fig 5-5 Hydrograph of the Khlong Tha Dan River at Ban Khlong Si Sook G.S

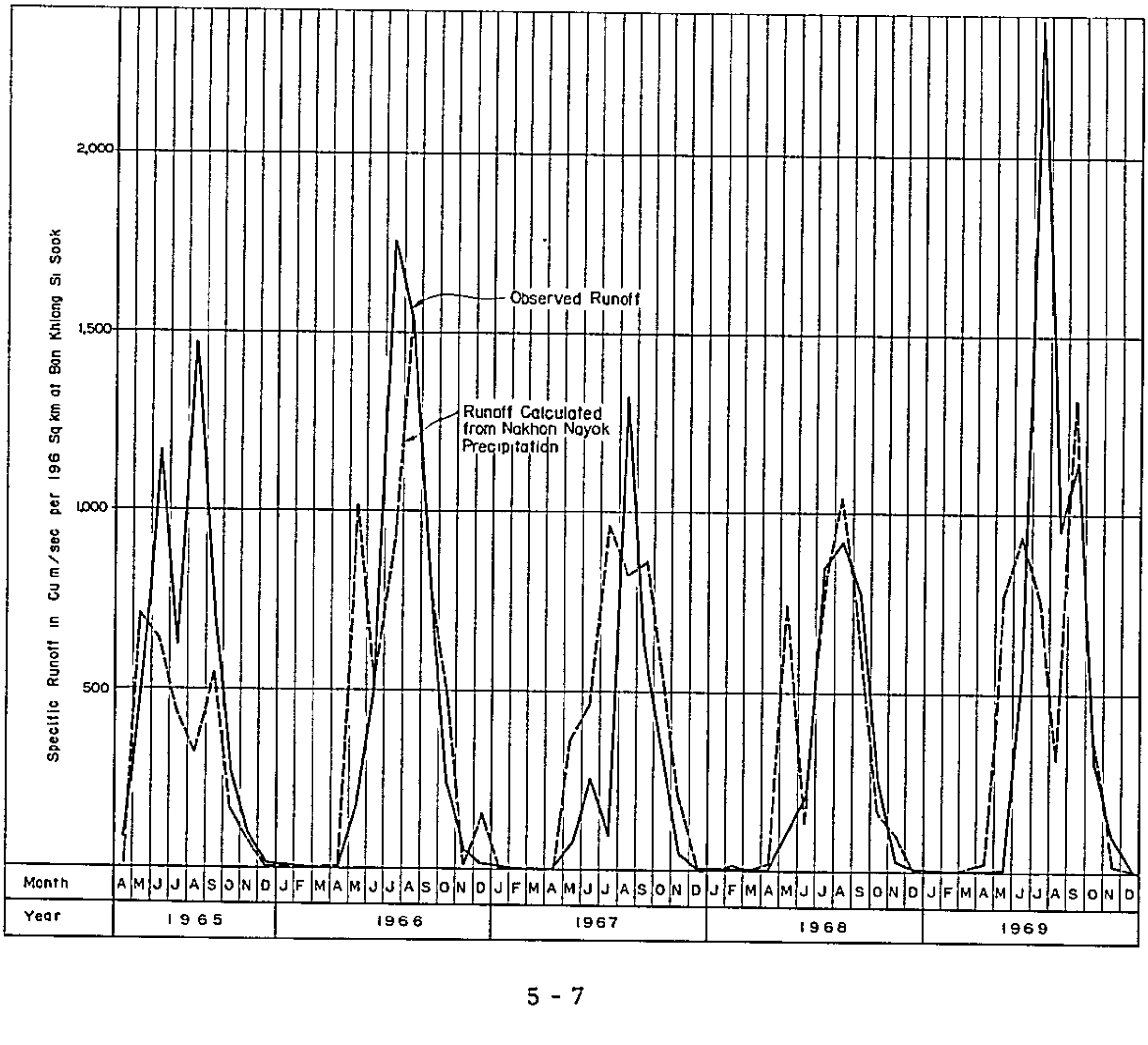


Table 5-4 Runoff at Ban Khlong Si Sook Gaging Station

(Unit : Cu.m/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1965	-	-	-	2.95	16.2	39.2	20.0	47.5	25.2	8.72	3.08	0.60	-
1966	0.17	0.10	0.07	0.04	5.72	20.2	56.6	49.6	27.3	7.70	1.78	0.51	14.14
1967	0.12	0.05	0.00	0.08	2.42	8.79	31.4	42.9	21.0	10.60	1.38	0.32	9 92
1968	0.08	0.11	0.05	0.13	3.58	6.89	27.2	29 7	25.7	8.31	1.03	0.20	8.58
1969	0.06	0.02	0.01	0.00	0.11	18.59	76.8	30.62	38.36	9.62	3.41	0.78	14.86
Total	0.43	0.28	0.13	3.20	28.03	93.67	212.0	200.32	137.56	44.95	10.68	2.41	733.66
Mean	0.11	0.07	0 03	0.64	5 61	18.73	42.4	40.06	27.51	8.99	2.14	0.48	12 87

Table 5-5 Runoff at Khlong Pun Damsite

(Unit : Cu.m/s-day)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1961	2.65	6.39	14.35	28.60	1,094.85	865.95	1,098.61	1,956.36	1,386.67	839.30	92 86	11.75	7,398.34
1962	2.65	3.55	0.89	33.71	865.53	1,192.72	1,451.75	1,079.56	1,305.57	600.77	42 90	9.97	6,589.57
1963	2.65	6.62	9.04	11.46	367.38	593.12	1,244.94	1,568.12	1,257.79	626.15	125.19	13.73	5,826.19
1964	2.65	2.44	1.61	10.04	654.02	450.76	1,028.22	1,016.90	880.26	674.93	40.51	9.97	4,772.31
1965	2.65	4.96	2.80	70.27	455.91	1,157.17	1,093.38	1,753.91	1,083.11	411.09	112.42	24.42	6,172.09
1966	6.79	3.66	2.47	2.25	202.59	712.46	1,977.04	1,802.84	1,131.66	386.30	81.89	22.40	6,332.35
1967	5.62	2.54	0.91	3 19	122.82	445.55	686.02	1,642.50	983.28	456.61	72 56	17.76	4,439.26
1968	4.50	4.08	2.01	4.49	150.75	401.45	1,268.71	1,323.61	1,093.55	401.24	64.06	14.93	4,733.38
1969	4.21	1.90	1.25	1.40	67.12	674.84	2,467.05	1,345.22	1,389.61	432.95	119.98	28.75	6,534 28
1970	2 65	5.94	3.06	8.41	455.08	616.12	917.58	949.29	770.82	285.90	43.09	13.34	4,061.28
Total	37.90	42.08	38.39	173.82	4,426.05	7,110 14	13,233 30	14,438 31	11,282 32	5,115.14	795.46	167.02	56,859.05
Mean	3.70	4.21	3.84	17.38	442.61	711.01	1,323 33	1,443.83	1,128.23	511.51	79.55	16.70	5,685 91

Table 5-6 Runoff at Khlong Tha Dan Damsite in Residual Basin

(Unit : Cu.m/s-day)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Total
1961	372.00	336.52	373 45	242.92	606.67	547.20	1,099 73	1,633.06	1,300.60	564 61	485.64	372.19	7,934.59
1962	372.00	336.22	263 85	243.47	582.04	582.30	1,578.31	1,058.82	823.17	538.99	480.28	372.00	7,231.45
1963	372.00	323.28	248.88	241.08	280.55	277 90	564.10	1,512.83	770.26	541.72	489.11	372.40	5,994.11
1964	372.00	348.10	248.08	240.93	311.33	456.27	540.82	706.82	521.59	546.96	480.02	372.00	5,144.92
1965	372.00	225.16	248.20	247.40	290.05	578.48	780.28	1,611.31	762.47	518.62	487.74	373.55	6,495 26
1966	372.45	224.23	248.17	240.09	262.85	290.72	1,230.99	1,616.57	865.05	515.96	454 60	373.33	6,695.01
1967	372.32	224.11	248.00	240.19	254.28	262.06	256.07	846.94	532.65	523.50	448.24	372.84	4,581.20
1968	372.20	232 27	248.12	240.34	257.28	257.32	566.65	801.43	588.38	517.56	449.77	372.53	4,903.85
1969	372.17	224.04	248.04	240.00	219.49	286 68	1,589.85	1,344.84	916.24	520.97	488.56	374.02	6,824.90
1970	372.00	251.53	248.23	240.76	288.89	351.23	528.94	532.90	509.83	505.18	360.30	372.36	4,562.15
Total	3,721.14	2,725.46	2,623.02	2,417.18	3,353.43	3,890.16	8,735.74	11,665 52	7,590.24	5,294.07	4,624.26	3,727.22	60,367.44
Mean	372.11	272.55	262.30	241.72	335.34	389.02	873.57	1,166.55	759.02	529.41	462.43	372.72	6,036 74

The runoff at the Khlong Tha Dan Dam in the residual dranage area, after deduction of the drainage area of the Khlong Pun Dam from that of the Khlong Tha Dan Dam, can be determined similarly by considering drainage area ratio. This runoff is tabulized in Table 5-6.

Further, the inflows into the Khlong Pun Reservoir from the Huai Som Thung Yai and Huai Nang Rong Rivers were determined by the method descibed below. Monthly duration curves were prepared for the runoffs observed at Ban Khlong Si Sook from May 1965 to December 1969, and from the average duration of each month for the 4-year 9-month period the monthly average duration of each intake site was assumed from the ratio of drainage area. The inflow in each month was determined based on these duration curves.

These monthly inflows are indicated in Table 5-7.

Table 5-7 Monthly Inflow from the Huai Nang Rong River and the Huai Som Thung Yai River into the Khlong Pun Reservoir

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
2.65	1.53	0.89	1.37	64.33	240.18	610.84	605.67	493.02	200.44	40.32	9.97

The annual evaporations (evaporation from A pan) observed at Ban Khlong Si Sook from 1966 to 1970 are as indicated below.

1966	1,827 mm
1967	1,737
1968	1,740
1969	1,571
1970	1,969
Average	1,669 mm

The annual precipitations observed at Ban Khlong Si Sook from 1966 to 1970 are as indicated below.

1966	4,021 mm
1967	2,865
1968	2,866
1969	3,250
1970	2,963
Average	3,193 mm

The annual runoffs observed at Ban Khlong Si Sook from 1966 to 1969 are as indicated below.

1966	5,212 cu.m/sec
1967	2,783
1968	3,160
1969	5,472
Average	4,155 cu.m/sec

Therefore, the runoff coefficient of the Khlong Tha Dan River is approximately 0.55 and the evapotranspiration is approximately 45% of precipitation.

The net evaporation-precipitation correction factor is approximately estimated as follows:

(Net Correction) = (Evapotranspiration) - (Evaporation from reservoir furface)

= (Precipitation) x (1 - 0.55) - 1,669

= 3,193 x 0.45 - 1,669

≒ - 230 (mm)

The total loss from the reservoir, including evaporation loss, was therefore adopted at 600 mm annually.

Since the runoff records in the project area are available for only 4 years, it is impossible to estimate maximum probale flood by statistical methods based on runoff records. Therefore, the flood discharge of Khlong Pun Dam was estimated roughly 1,200 cu.m/sec, and that of Khlong Tha Dan Dam 1,380 cu.m/sec by the Rational Formula.

As there are no data available in connection with sedimentation in the project area, the amount of sedimentation to be expected in the reservoirs of this Project was estimated conservatively based on sedimentation records obtained at reservoirs in Japan.

The volume of sedimentation at 52 reservoirs of drainage areas larger than 60 sq.km and storage capacities more than 1,000,000 cu.m are plotted in Fig. 5-6 with a correlation to geological, topographical conditions and rainfall in the basins. The geological conditions within a basin are classified into three groups according to lithologic character. Namely,

A : Basins mainly comprised of sedimentary rocks of the Paleozoic or Mesozoic eras.

B : Basins mainly comprised of acidic plutonic rocks, hypabyssal rocks or metamophic rocks represented by crystalline schist.

C : Basins mainly comprised of sedimentary rocks or volcanic rocks of the Cenozoic era.

The volume of sedimentation in each group is plotted in Fig. 5-6 as a function of the product of maximum annual precipitation and the relative relief of topography. Eroded fragmentary rocks in the basin are considered to be transported into the reservoir at time of rainfall. The relative relief is defined as the mean value of the difference in height between the highest point and the lowest point in a square grid of 16 sq.km.

These square grids are provided dividing up the entire basin and the mean value of their relative reliefs is taken.

For the catchment area of the proposed damsite, the conditions governing sedimentation are as follows:

Geological condition: Group A

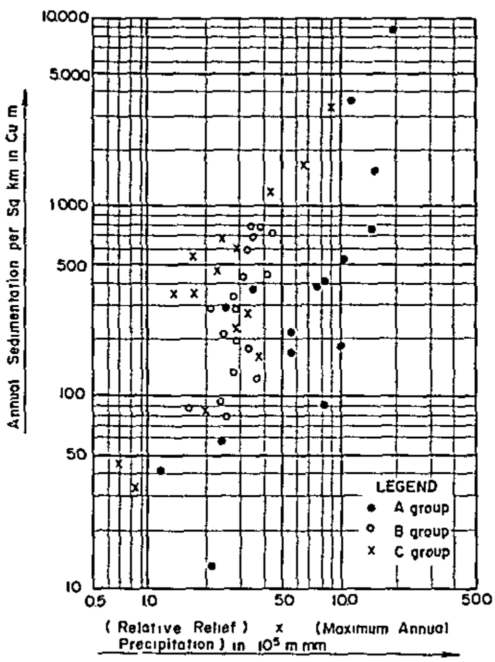
Maximum annual precipitation: approx. 4,000 mm

Relative relief: approx. 470 m

(Maximum annual precipitation) x (Relative relief) = 18.8 x 10^5 m·mm

Therefore, taking the upper limit value of Group A in Fig. 5-6, the annual sedimentation was calculated to be 2,000 cu.m per square kilometer.

Fig 5-6 Correlation between the Sedimentation in Reservoir and (Relative Refief) x (Maximum Annual Precipitation)



5.2 Geology

A. General

The rocks distributed in the project area are volcanic complex consisting of rhyolite, andesite, agglomerate, etc. and are covered on top by sandstone of the Mesozoic era. The boundary between the volcanic complex and the sandstone just passes the proposed Khlong Pun Dam site, and extends in a roughly north-south direction. This boundary, according to a geological map issued by the Department of Mineral Resources of Thailand, is what is called an unconformity which is a basal plane of sand deposited and solidified on a volcanic complex at the seabottom. For this reason, this boundary may be slightly soft and weak, but it is thought that, even if it were to be at the dam foundation, it can adequately be treated.

Each rock comprising the volcanic complex, which is fresh, has few fissures and is extremely sound.

In this area, as described in Chapter 6-1, there is a flat plane at EL. 400 - 500 m, where weathering is thought to be considerably deep. However, this is not necessarily a disadvantageous condition in construction of civil structures such as dams and power stations, and rather, it is possible to take advantage of this situation.

Limestone presents a unique feature called karst topography which can be observed readily from aircraft. However, since no limestone was found with such features as far as seen from aircraft, it is inconceivable that there would be leakage from the reservoir through caves in limestone. On the other hand, volcanic rocks cover a wide area. The geological age of this volcanic complex is pre-triassic and is older than the sandstone of the Mesozoic era lying. As the sandstone of the Mesozoic era is marine deposit, it would have to be deposited on top of volcanic complex at the seabottom. If there had been caves in the volcanic complex at the time this deposition was taking place, these caves would have been filled by the deposited materials. Therefore, with respect to the volcanic rocks distributed in the project area, there is no fear that large-scale leakage of water from the reservoir would occur.

At roughly horizontal parts of the various rivers and streams flowing through the flat area of EL. 400 - 500 m mentioned previously, there were stagnant pools of water at manyy places from which no discharge was taking place. If the bedrock were absorbent such pools not have existed. Further, the fact, that pools existed in the dry season when the rate of evaporation is rather high, indicates that the ground water tables around the pools were higher than the water level of the pools and the underground water was being supplied to the pools. From this fact it is surmised also that the bedrock is watertight.

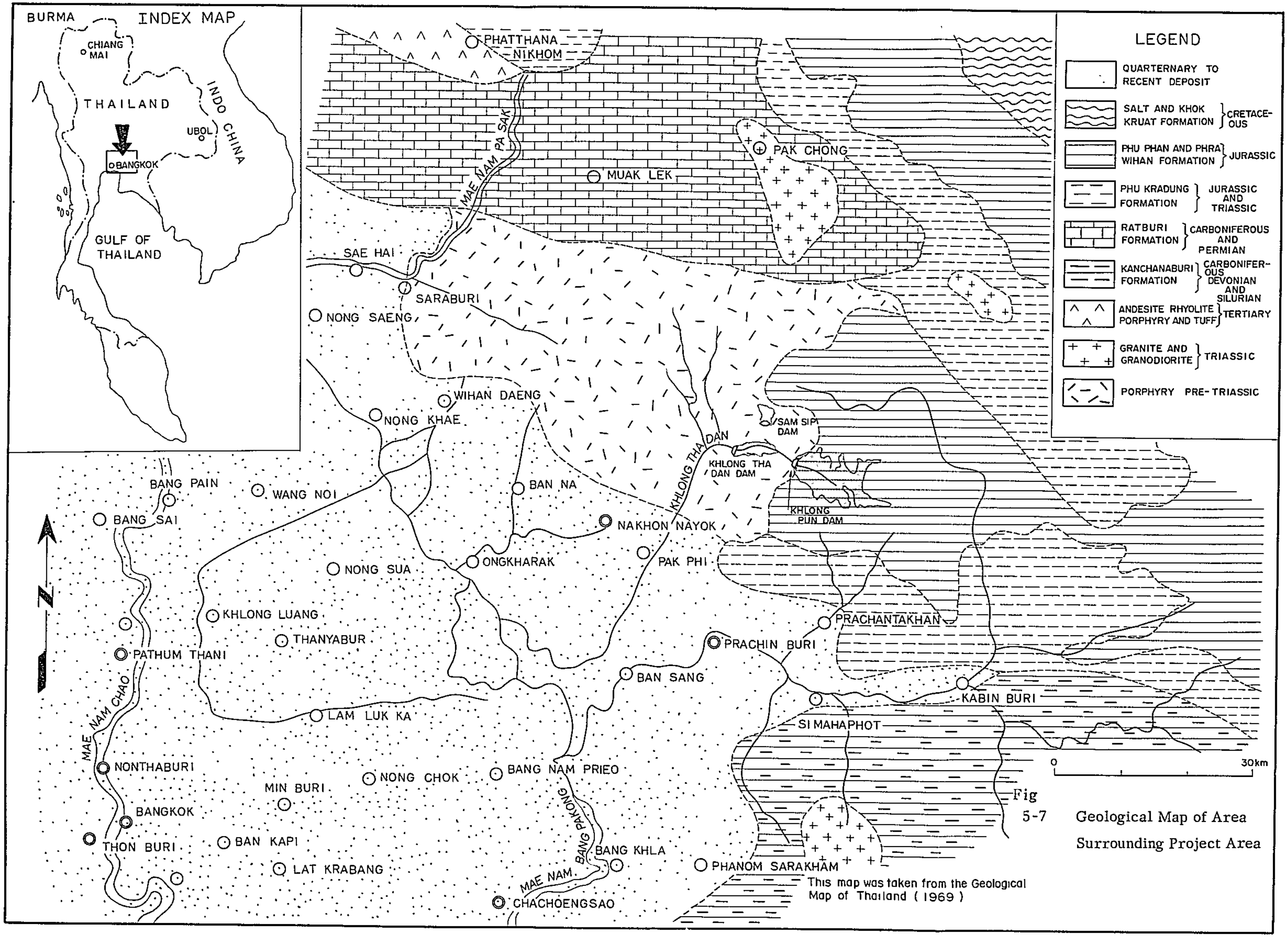


Fig 5-7 Geological Map of Area Surrounding Project Area

However, in the arêa surrounding Khlong Pun Reservoir, there are one or two places of low elevation near the boundary of the basin, and since these parts are expected to be deeply weathered, care should be exercised in regard to leakage from the reservoir.

B. Geology of Foundation for Structure

Khlong Pun Dam

There is a bedrock of rhyolite at the river bed. The rock forming Heo Narok Waterfall immediately downstream of the damsite is also rhyolite, and is compact and extremely sound.

Mesozoic sandstone lies on top of this rhyolite. The sandstone is light brown to white in color, coarse-grained, and is slightly soft in comparison with the rhyolite, but as a foundation for a dam, if fresh, it is of adequate hardness regardless of the type of the dam.

It is expected the hilltops at both left and right banks will be found to be deeply weathered, but the weathered layers of both slopes of the Khlong Tha Dan River will be thin. The boundary between the abovementioned rhyolite and sandstone is probably not tight, and it is expected this portion will have clay material and be conglomeratic and slightly soft.

No fault could be found because the area is widely covered with topsoil and river deposits, but, as this area is stable land, there should be no large-scale faults.

Khlong Pun Power Station and Penstock

The topography around the proposed site for Khlong Pun Power Station and the penstock is fairly rugged. The bedrock is rhyolite which is extremely sound, and as it appears that deposits of talus are thin there are no problems to be foreseen so far as the present reconnaissance is concerned.

Khlong Pun Headrace Tunnel

The bedrock is rhyolite and extremely sound. There are no problems for the construction to be found at the moment. However, the topography at the intake site is gently sloped and it is expected that weathering will be deep and it is desirable for attention to be paid to this point.

Intake Tunnel from Khan Basin

The bedrock is a volcanic complex consisting of extremely sound rhyolite, andesite, agglomerate and infrequently basalt over almost the entire length, although there may be Mesozoic sandstone on the top of volcanic complex in the section near the tunnel outlet. The boundary between the two would be inclined down toward the tunnel outlet at a small angle, which would be somewhat of a problem in excavation of the tunnel. The vicinity of the tunnel outlet as same as in the case of the intake of the headrace tunnel is of a gently sloped topography, and weathering is expected to be deep so that caution must be exercised in this regard.

Khlong Tha Dan Dam

The slopes of the left and right banks are symmetrical to present a favorable topography for a damsite while the river bed is more or less flat. The bedrock is andesite which when fresh is extremely sound. As both banks are covered by dense jungle growth, it is not clearly known but the weathered stratum may be deep. The river bed is covered with sand and gravel, but the thickness is small while weathering of the bedrock cannot be thought to be very deep judging from the conditions in other areas. The almost entire damsite area is covered with talus or sand-gravel and nothing is known about faults, which must await clarification through future investigations.

Khlong Tha Dan Power Station and Penstock

The bedrock is agglomerate and extremely hard. The deposits of sand-gravel at the river bed of the Khlong Tha Dan River are very shallow and there are wide areas in which the bedrock is exposed. However, the powerhouse site is widely covered by dense jungle so that details are not known, but it is expected there will be some river terrace deposits and talus.

The bedrock along the penstock route is also agglomerate or rhyolite with weathered surface layer which may be slightly deep.

Khlong Tha Dan Headrace Tunnel

The bedrock is a volcanic complex of agglomerate, rhyolite and andesite, and these rocks are extremely hard. Problems such as faults are not known at present, but judging from the lithologic character it apperas there will be nothing serious.

Sam Sip Reservoir

It is thought the bedrock of the reservoir will be chiefly rhyolite, but there may be a possibility of Mesozoic sandstone being present in a continuation from the Khlong Pun damsite.

As the surface of the proposed reservoir area is thought to be deeply weathered, it is surmised that excavation within the reservoir to increase storage capacity could be carried out comparatively easily, but if the depth of excavation is to reach down into bedrock, blasting-excavation will be required, since the bedrock is extremely hard. As the bedrock of the reservoir consists of such hard rock, leakage through the bedrock is unthinkable. However, if there should happen to be Mesozoic sandstone, it is expected that the boundary between this rock and the rhyolite will be slightly weak, but even if there should be such a weak boundary, the leakage through it will hardly be a problem.

Sam Sip Dams

As for the type of dam, it is conceivable for a fill type to be constructed using the excavated material for the increment of the capacity of reservoir. Bedises a main dam, it is thought two dikes will be necessary for reasons of topography. At these sites, weathering of the surface stratum would be deep while the topography is gently sloped, and there are no outcrops of bedrock to be seen. It is assumed that the bedrock probably consists of rhyolite, but there may be Mesozoic sandstone at the foundations of the dikes.

Sam Sip Power Station and Penstock

The topography in the vicinity of the powerhouse site is slightly gently sloped, but near the surge tank the rock is exceedingly rugged. There is no talus deposit at this rugged part, but at the slightly gently sloped part the talus deposit is thick with scattering of large boulders. The bedrock is mainly andesite but rhyolite may be partially present. Since both the andesite and rhyolite are very sound, there should be no big problem in excavation for an embedded penstock or underground power house.

Sam Sip Headrace Tunnel

The bedrock is a volcanic complex of rhyolite and andesite, and these are very hard. Problems such as faults are not clearly known at present, but judging from the lithologic characters it appears there will be no serious problem.

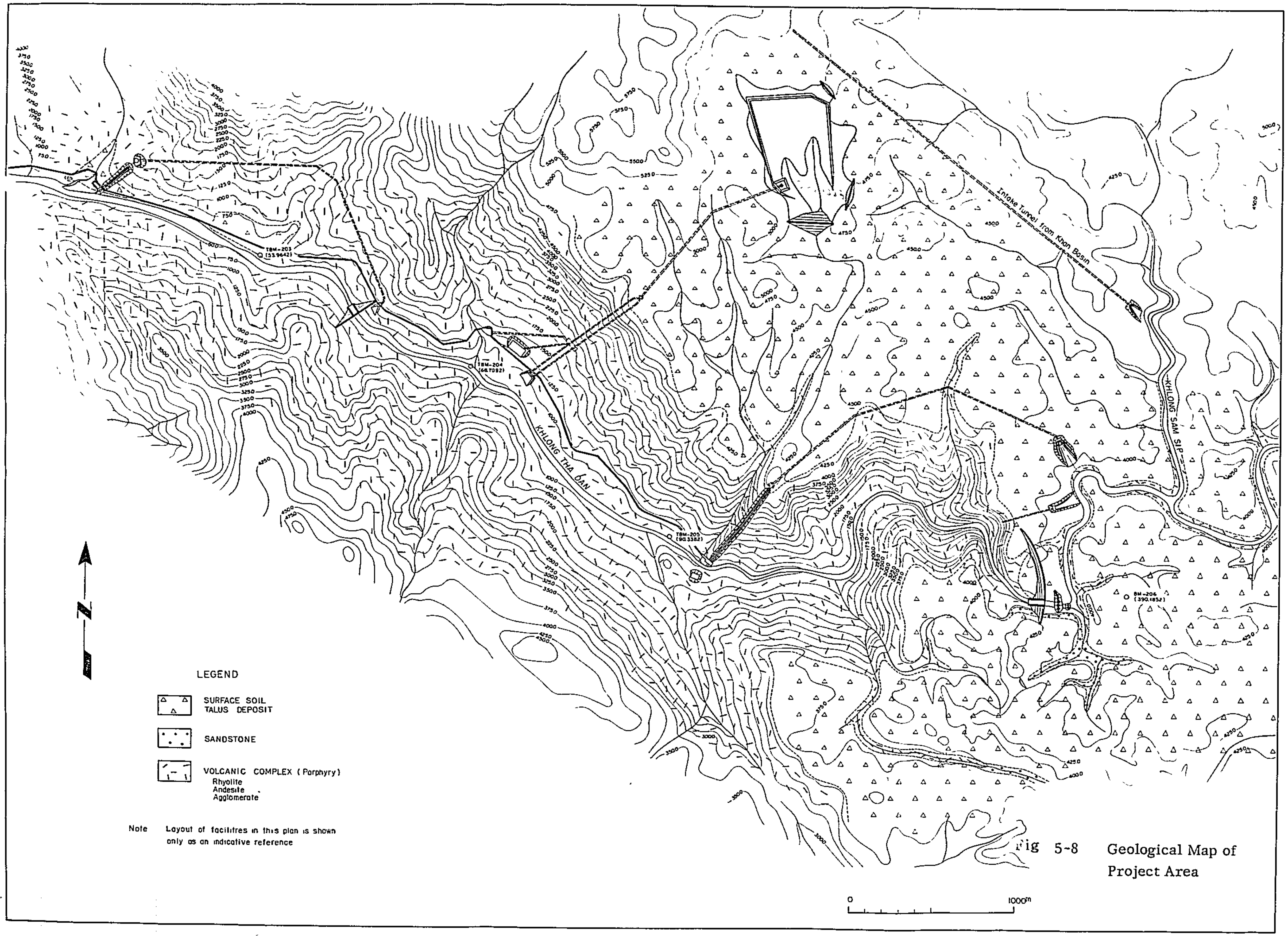


Fig 5-8 Geological Map of Project Area

CHAPTER 6
PLAN OF DEVELOPMENT

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CHAPTER 6. PLAN OF DEVELOPMENT

6.1 Introduction

In regard to a power development scheme for the Khlong Tha-Dan Project there is a reconnaissance report* made by a Japanese Government survey team (Chief, Mr. Takeshi Tokuno). The main point of Mr. Tokuno's report is to construct a dam at the upstream of a waterfall called the Heo Narok which has a head of approximately 250 m and to provide a power station below the waterfall. The second point is to divert the water of the Huai Nang Pong River and the Huai Sam Phung Yai Rivers, adjacent to the Khlong Tha Dan River, to the Khlong Tha Dan River basin through intake-tunnels. The third point is that since the project site is close to Bangkok, and moreover, has potential energy of high head, an idea of pumping-up power station could be contemplated.

Since the main objective of the Tokuno Team was the study on the Nam Sai Yai Basin adjacent to the Khlong Tha Dan River Basin, the data obtained for the report was no more than that from field inspection and topographical maps of 1/50,000-scale.

However, as a result of the present investigations, it was convinced that the Tokuno Report, in spite of being based on sufficient data, had obtained a grasp of the essential points.

In May 1970, Mr. Minoru Kubota, a planning expert, sent to NEA from OTCA of Japan, upon studying the Tokuno Report on topographical maps, suggested a possibility to install a recirculating pumping-up station.

Compared to the above, sufficient data (1/10,000-scale topographical maps, etc.) have been obtained in the present survey.

Physical Geography

In view of the actual observation over the project area from aircraft, it was found that the area was comprised of 4 steps of horizontal flat plains. The first and lowest step is a vast plain, namely the Bangkok Plain. The second plain is at an elevation of 400 to 500 m, over which precipitation has eroded the plain to form the gorge through which the Khlong Tha Dan River flows. In this Project, construction of the Khlong Pun Dam is planned upstream

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* Appendix of Report on Basic Studies for Development of Hydraulic Potentials of the Nam Sai Yai, "Report on Reconnaissance of Khlong Tha Dan Basin, "June 1965, Overseas Technical Cooperation Agency, Government of Japan.

of the Khlong Tha Dan Dam site and the Khlong Pun Reservoir will be created on this second plain area (see Fig. 5-8). The third plain is at an elevation of approximately 700 m and is located at the southeastern part of the project area. The fourth plain area is at a level of approximately 1,200 m and occupies the northern part of the project area. Mt. Khao Khieo is located in this plain area.

At the immediately downstream of the Khlong Pun Dam site, a wall of volcanic rock is massively exposed in a vertical direction and within a head of approximately 250 m a three-stages waterfall is formed. This magnificent waterfall is named the Heo Narok.

The waterfalls of the Huai Nang Pong River and of the Huai Sarika River also flow over exposed volcanic rocks.

The project area on the whole is a dense evergreen forest and is covered by green vegetation except some portions such as rivers, waterfalls, vertical cliffs and exposed bedrock on plains.

A major item of the development is to construct the Khlong Pun Dam at the immediately upstream of the Heo Narok Waterfall to create the Khlong Pun Reservoir and to generate power at a powerhouse which will be provided at the downstream of the waterfall.

The Khlong Pun Reservoir, topographically speaking, will be formed on the second-stage plain at elevations of approximately 400 to 500 m so that the reservoir area will be comratively large. The catchment area of the reservoir is approximately 153 sq.km.

The Khlong Tha Dan Reservoir will be formed in steep gorge and the reservoir area will be relatively small. The catchment area of the reservoir is approximately 16 sq.km.

Since the Khlong Tha Dan River flows through a massive volcanic rock area, there is almost no sedimentation to be seen. The water is extremely clear and the three reservoirs should become clear, scenic artificial lakes.

The Huai Nang Rong River and the Huai Sam Phung Yai River are located at the north-west of the Khlong Tha Dan River. The upstream parts of these rivers are on the second step plain area. The combined drainage area (called here the Khan Basin) is 170 sq.km which is equal to or larger than the drainage area of the Khlong Pun Dam. If intake of water were to be carried out from these two rivers to the Khlong Tha Dan Reservoir or the Khlong Pun Reservoir, the inflow into either reservoir would be more than doubled.

These two rivers also flow through a massive volcanic rock area and the waters are extremely clear.

In general, when there are steep mountains along rivers with the tops of the mountains being relatively flat, there are cases when recirculating-type pumped-storage hydroelectric power development projects are planned, by building a reservoir at the river below (lower reservoir) and another reservoir on the flat area above (upper reservoir). This project area, according to the topography, has flat land at places of high elevation and it would be possible that a site for a recirculating-type pumped-storage is available. The Sam Sip site at the foot-hills of Mt. Khao Khieo is a location which has such a possibility as seen from the physical geography.

6.2 Study of Plan of Development

When the various features of the Project are combined, numerous alternative plans can be conceived. The three alternatives introduced below are the results of careful selection after comparison of the many plans conceivable.

In carrying out the selection, economic analysis were made the basis. The construction costs which would have great weight in evaluation of the economics were obtained by calculating rough estimated figures of work quantities from preliminary layouts drawn in 1/10,000-scale topographical maps, and multiplying these quantities by recent unit construction costs in Thailand.

Study of Plan of Development

In planning the development of the Khlong Tha Dan Basin, two cases can be conceived; to develop its own river basin in a conventional way to satisfy the future peak power demand of Bangkok, or to develop the project as the pumped storage, since the site is relatively close to the capital area and provides conditions to be able to utilize easily surplus energy of large-scale thermal and nuclear power plants around Bangkok at midnight. In the development of pumped-storage power generation, there are two forms —— a "recirculating-type pumped-storage power station" which does not need any water supply from its own drainage area and a "multi-use pumped-storage power station" which water is to be supplied by its own drainage area and therefore is capable of producing electric energy by the inflow.

Therefore, in the study of the development planning for the Khlong Tha Dan River, an examination was first made for the conventional development plans, of which the most economical one was selected. Then, alternative plans of development as pumped-storage type were studied modifying the conventional plan of development selected.

(a) Plan of Development of Conventional Type

As for the conventional development planning, the three cases below are conceivable.

Plan A

The Khlong Pun Dam would be built at immediately upstream of the Heo Narok Waterfall on the upper reaches of the Khlong Tha Dan River from which a headrace tunnel of approximately 2 km long would lead to a powerhouse provided on the right bank side downstream of the Heo Narok Waterfall to utilize the head of approximately 300 m for peak power generation.

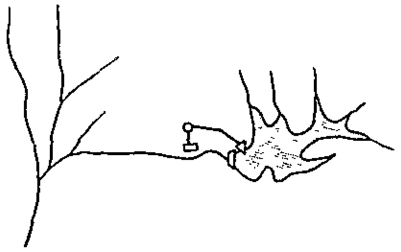
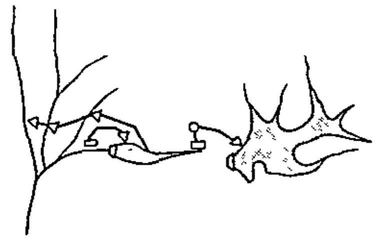
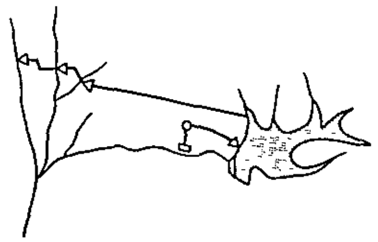
Plan B

In addition to the project facilities of Plan A, the Khlong Tha Dan Dam would be built to provide Khlong Tha Dan Regulating Pond in the downstream of the river. This Khlong Tha Dan Regulating Pond would take in water from the two adjacent rivers, the Huai Nang Rong River and the Huai Sam Phung Yai River, through a relatively short diversion tunnel. Water of this regulating pond would be conveyed by a headrace tunnel approximately 2 km long to the Khlong Tha Dan Power Station to utilize a head of approximately 50 m.

Plan C

In addition to the facilities of Plan A, there would be provided an intake tunnel from the adjacent rivers, the Huai Nang Rong River and the Huai Sam Phung Yai River, to the Khlong Pun Reservoir. The intake tunnel would be longer than in Plan B and would be as long as 14.5 km, but the water thus drawn could be utilized at the high-head Khlong Pun Power Station. Features of these development plans are indicated in the Table 6-1. As a result of the studies, Plan A and Plan C are found to be economically superior to Plan B, having benefit-cost ratios of 1.12. However, when the annual surplus benefits (B-C) of Plan A and Plan C are compared, it is ฿4.7 x 10^6 for Plan A while it is ฿7.7 x 10^6 for Plan C, so that Plan C is of greater advantage. This is because of the fact that the large amount of energy may be produced at the Khlong Pun Power Station with the increased water taken from the two adjacent rivers, and therefore the development plan became economical and advantageous, even though the expenditure for constructing an intake tunnel slightly increases the total construction cost.

Table 6-1 Comparison of Plan of Development of Conventional Type

Item \ Plan		A	B			C
Layout						
Power Station		Khlong Pun P.S	Khlong Pun P.S	Khlong Tha Dan P.S	Total	Khlong Pun P.S
Reservoir						
Catchment Area	km^2	152.7	152.7	369.9 (169.1+170.8)		292.8
Annual Inflow	$10^6 m^3$	295.0	295.0	563.2		491.3
Nor. High Water Level	m	416.0	416.0	110.0		416.0
Effective Drawdown	m	11.0	11.0	10.0		11.0
Effective Storage Capacity	$10^6 m^3$	229.0	229.0	7.0		229.0
Dam						
Type		Concrete	Concrete	Concrete		Concrete
Height x Crest Length	m	62 x 590	62 x 590	56 x 290		62 x 590
Volume	$10^3 m^3$	234	234	167		234
Water Way						
Headrace Tunnel	km	2.0 (D=4.0)	2.0 (D=4.0)	2.1 (D=5.7)		2.0 (D=5.0)
Tunnel from Adjacent Rivers	km	-	-	7.0 (3.0-4.0)		14.5 (2.9-3.7)
Power Plant						
Effective Head	m	295.0	295.0	50.0		295.0
Max. Power Discharge	m^3/S	30.0	30.0	60.0		48.0
Installed Capacity	MW	75.0	75.0	25.0	100.0	120.0
Annual Energy Production	10^6 kWh	201.6	201.6	64.9	266.5	332.1
Construction Cost	10^6Baht	537.4	537.4	622.9	1,060.3	873.0
Benefit - Cost Ratio		1.12			0.75	1.12
Surplus Benefit	10^6฿	4.7			19.2	7.7
Salable Energy Cost	฿/kWh	0.20			0.30	0.20
Power Cost	฿/kW	7,387			10,931	7,500

(b) Plan of Development of Pumped-Storage Type

As a result of the study mentioned in the preceding section it was learned that among the plan of development of conventional type Plan C would be most advantageous.

Therefore, in planning pumped-storage type development, it would be economically advantageous to modify the Plan C into a pumped-storage power station. In this case, it is necessary for the project to provide a lower reservoir, the Khlong Than Dan, and two alternative plans of development are conceivable topographically, which will be explained as follows.

1) Plan R

In a recirculating-type pumped-storage development plan, it is conceivable to add to Plan C of the preceding section a recirculating-type pumped-storage underground power station, building an upper reservoir on a terrace of EL. 475 m at the right bank of approximately 1 km downstream of the Khlong Pun Power Station, and utilizing the Khlong Tha Dan reservoir as the lower reservoir. The Khlong Tha Dan Power Station will be provided also at the downstream of the Khlong Tha Dan Dam.

2) Plan M

It is conceivable to use the high-head Khlong Pun Reservoir as an upper reservoir and the Khlong Tha Dan reservoir as a lower reservoir, developing the Khlong Pun Power Station as an underground type. The Khlong Tha Dan Power Station will be provided at the downstream of the Khlong Tha Dan Dam. This is a multi-use type pumped-storage development.

The main features of these development plans are indicated in Table 6-2. According to the results of analysis the benefit-cost ratios of Plan M and Plan R are 1.03 and 1.07 respectively so that both alternatives would be promising.

The benefit-cost ratios of Plan C, Plan R and Plan M rounded out as 1.1, 1.0 and 1.1, respectively, because of the degree of accuracy of this survey is quite rough.

All three can be said to be promising, but the superiority of any one of them cannot yet be decided.

6.3 General Description of Schemes of Development

1) Introduction

In the studies of the development plans in the preceding paragraph, comparisons were made of a development plan of conventional type, Plan C, and a pumped-storage type development plans, Plan R and Plan M. The ratios of annual benefits and annual costs of these development plans for an analysis period of 50 years are 1.1, 1.1 and 1.0, respectively, while the differences between annual benefits and annual costs (surplus benefit) are ₿7.7 x 10^6, ₿17.4 x 10^6 and ₿7.9 x 10^6, respectively.

It is difficult to say which of these proposed development plans is superior, because of the differences in development scales and in development stages, and also because of the fact that the economic superiority would be decided by the electric power situation of Thailand comprised of factors such as the future growth in power demand, load curves and peak supply capacity. It should also be noted the estimated construction costs can be significantly changed due to the results of the future geological surveys and design of various structures based on more accurate topographical maps.

Here, the outlines of the conventional type development plan, Plan C, pumped-storage type development plans, Plan R and Plan M, will be described.

2) Conventional Type Development Plan : Plan C

A concrete gravity dam of approximately 62 m high would be constructed immediately upstream of the Heo Narok Waterfall in the upstream of the Khlong Tha Dan River by which the Khlong Pun Reservoir with effective storage capacity of 229 x 10^6 cu.m would be created. Water would be conducted from this reservoir by a pressure tunnel of approximately 2 km long to a outdoor powerhouse, downstream of the Heo Narok Waterfall and on the right bank, for peak power generation, with maximum output of 120 MW, by utilizing the head of approximately 300 m.

Further, the catchment area of the Huai Nang Rong River and the Huai Sam Phung Yai River, which are adjacent rivers of the Khlong Tha Dan River, is approximately equal to that of the Khlong Tha Dan River. It is found advantageous economically to conduct a maximum 25 cu.m/sec of water of these two rivers to the Khlong Pun Reservoir to utilize it for power generation. Therefore, this plan calls for the runoff of these rivers to be drawn to the Khlong Pun Reservoir.

3) Pumped-Storage Development Plan : Plan R

This is a plan in which the Sam Sip Power Station, a recirculating-type pumped-storage power station is added to the conventional type of plan described in 2) above.

The Khlong Tha Dan Dam, 54 m high, would be constructed at a point approximately 2.5 km downstream of the Khlong Pun Power Station to provide the Khlong Tha Dan Regulating Pond with an effective storage capacity of 7×10^6 cu.m. Another dams would be built at around EL. 475 m on the right bank side at approximately 1 km downstream from the Khlong Pun Power Station to provide the Sam Sip Regulating Pond with an effective capacity of 3×10^6 cu.m which is sufficient for generating peak power for six hours.

The Sam Sip Pumped-Storage Power Station would utilize the Khlong Tha Dan Regulating Pond as the lower reservoir and the Sam Sip Regulating Pond as the upper reservoir. This will be a recirculating-type pumped-storage power station (underground), which will pump up water from the Khlong Tha Dan Regulating Pond to the Sam Sip Regulating Pond, using surplus power at midnight and discharging the water of the Sam Sip Regulating Pond for peak power generation during the hours of peak loads. The head between the two would be 360 m and the maximum output of the power station would be 400 MW.

The Khlong Tha Dan Regulating Pond, besides being enough to be able to operate for pumping up storage, will also be enough to be able to regulate the discharge used for peak power generation at the Khlong Pun Power Station. Downstream from this regulating pond, water would be conveyed through a headrace tunnel of approximately 2 km long to the Khlong Tha Dan Power Station which will be provided on the right bank side. The head of approximately 50 m, and the maximum output will be of 20 MW.

4) Pumped-Storage Development Plan : Plan M

This is a plan to utilize the Khlong Pun Power Station described in 2) above as a pumped-storage power station of underground type.

In other words, the Khlong Pun Reservoir would be utilized as the upper reservoir and the Khlong Tha Dar Regulating Pond, described in 3) above would become the lower reservoir. Surplus power at midnight would be used to pump up water from the Khlong Tha Dan Regulating Pond to the upper Khlong Pun Reservoir which combines with the recirculated water with water from its own drainage area, and thus generate power generation at peak load hours. The plan can be called as multi-use type pumped-storage power development plan of 400 MW installed capacity.

In this case, the Sam Sip Pumped-Storage Power Station mentioned in 2) was not included in the plan. However, should peak loads in Thailand increase sharply in the future and a shortage of supply capacity be brought about, it might be necessary to consider the combined development plan of both the Sam Sip Pumped-Storage Power Station of 2) and this Khlong Pun Multi-Use Pumped-Storage Power Station.

In the development plans of 2), 3) and 4) mentioned above, intake of water from the two adjacent rivers, the Huai Nang Rong River and the Huai Som Phung Yai River, into the Khlong Pun Reservoir is taken into account.

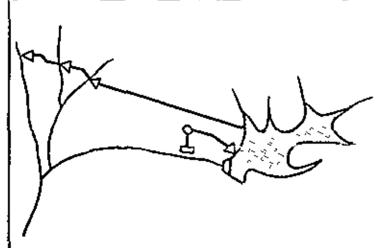
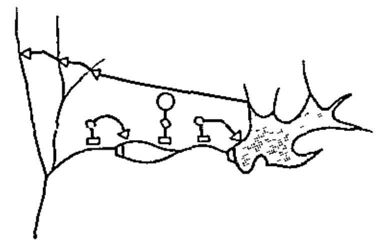
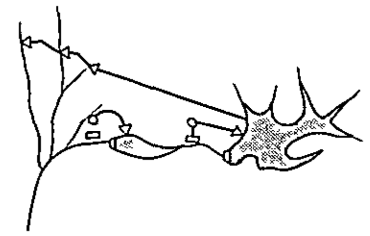
However, as for the Huai Nang Rong River, it has, at its downstream part, the Nang Rong Waterfall, where tourism is fairly well developed, flourishing as a recreation spot for the people. At the downstream of the intake site on the Huai Som Phung Yai River, another adjacent river, there is also the Wong Ta Kai Royal Botanical Garden, and there is an intake facility for this garden. Therefore, any intake of water from the two rivers to the Khlong Pun Reservoir would require due consideration of such circumstances.

5) Capacity of Reservoir

The seasonal fluctuations and yearly fluctuations of the river at the Khlong Pun Dam site are as shown in a mass curve of Fig. 6-1. This mass curve has been prepared based on the runoff data of the 19 years from 1952 through 1970 described in Chapter 5, 5.1, Hydrology. The average total runoff at this site during the rainy season of the 6 months from May through October in an average year is 480.5 x 10^6 cu.m, while on the other hand, during the dry season of the 6 months from November through April, the average toal runoff is only 10.5 x 10^6 cu.m. The total annual runoff of a mean year is 491.3 x 10^6 cu.m whereas that of wet year (1961) is 639.2 x 10^6 cu.m and that of a dry year (1970) is 350.9 x 10^6 cu.m. In order to regulate this fluctuating runoff and to utilize the water resources to the maximum, it is necessary to plan a reservoir of large capacity capable of annual regulation.

On the other hand, in view of the topographical characteristics of the Khlong Pun Damsite, it is thought to be difficult to raise the elevation of the high water level of the Khlong Pun Reservoir above 416 m. Taking the high water surface level at 416 m, the total storage capacity would be 319 x 10^6 cu.m. Assuming its appropriate drawdown as 11.0 m, the effective storage capacity of the reservoir would be 229 x 10^6 cu.m. (See Fig. 6-2).

Table 6-2 Comparison of Selected Plan of Development

Item \ Plan		C: Plan of Development of Conventional Type	R: Plan of Development of Pumped-Storage, Recirculating Type					M: Plan of Development of Pumped-Storage, Multi-Use Type		
Layout										
Power Station		Khlong Pun P.S	Khlong Pun P.S	Khlong Tha Dan P.S	Sub-Total	Pumping Up P.S	Total	Khlong Pun P.S	Khlong Tha Dan P.S	Total
Reservoir										
Catchment Area	km^2	292.8	292.8	309.2		-		292.8	309.2	
Annual Inflow	10^6m^3	491.3	491.3	521.6		-		491.3	521.6	
Nor. High Water Level	m	416.0	416.0	110.0		475.0		416.0	110.0	
Effective Drawdown	"	11.0	11.0	10.0		10		11.0	10.0	
Effective Storage Capacity	10^6m^3	229.0	229.0	7.0		3.0		229.0	7.0	
Dam										
Type		Concrete	Concrete	Concrete		Rockfill		Concrete	Concrete	
Height x Crest Length	m	62 x 590	62 x 590	56 x 290		35 x 320		62 x 590	56 x 290	
Volume	10^3m^3	234	234	167		450		234	167	
Water Way										
Headrace Tunnel	km	2.0 (D=5.0)	2.0 (D=5.0)	2.0 (D=5.0)		1.2 (D=5.5)		2.0 (D=6.5)	2.05(D=5.0)	
Tunnel from Adjacent Rivers	km	14.5 (D=2.9—3.7)	14.5 (D=2.9-3.7)					14.5 (D=2.9-3.7)		
Power Plant										
Effective Head	m	295.0	295.0	50.0		360		295.0	50.0	
Max. Power Discharge	m^3/s	48.0	48.0	48.0		134		160.0	48.0	
Installed Capacity	MW	120.0	120.0	20.0	140.0	400	540.0	400.0	20.0	420.0
Annual Energy Production	10^6kWh	332.1	332.1	59.5	391.6		391.6	332.1	59.5	391.6
						(600.0)	(600.0)	(600.0)		(600.0)
Construction Cost	10^6Baht	873.0	873.0	366.0	1,239.0	895.0	2,134.0	1,404.0	373.0	1,777.0
Benefit-Cost Ratio		1.12			0.93	1.15	1.07			1.03
Surplus Benefit	10^6Baht	7.7			-6.7	24.1	17.4			7.9
Salable Energy Cost	฿/kWh	0.20			0.24	0.28	0.26			0.24
Power Cost	฿/kW	7,500			9,124	2,307	4,074			4,362

Figures in parenthese show energy production by pumped-storage.

Fig 6-1 Mass Curve of Khlong Pun Reservoir

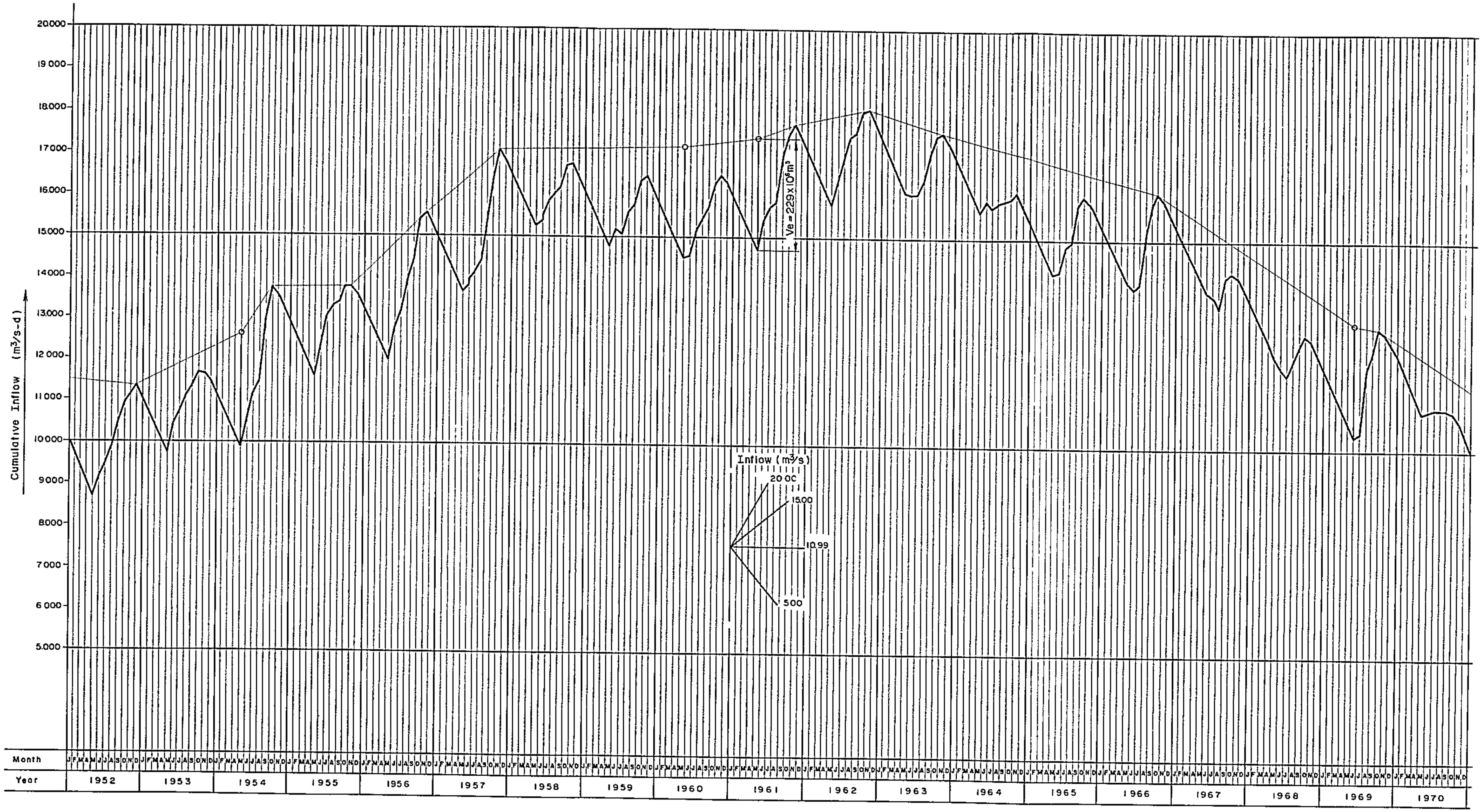
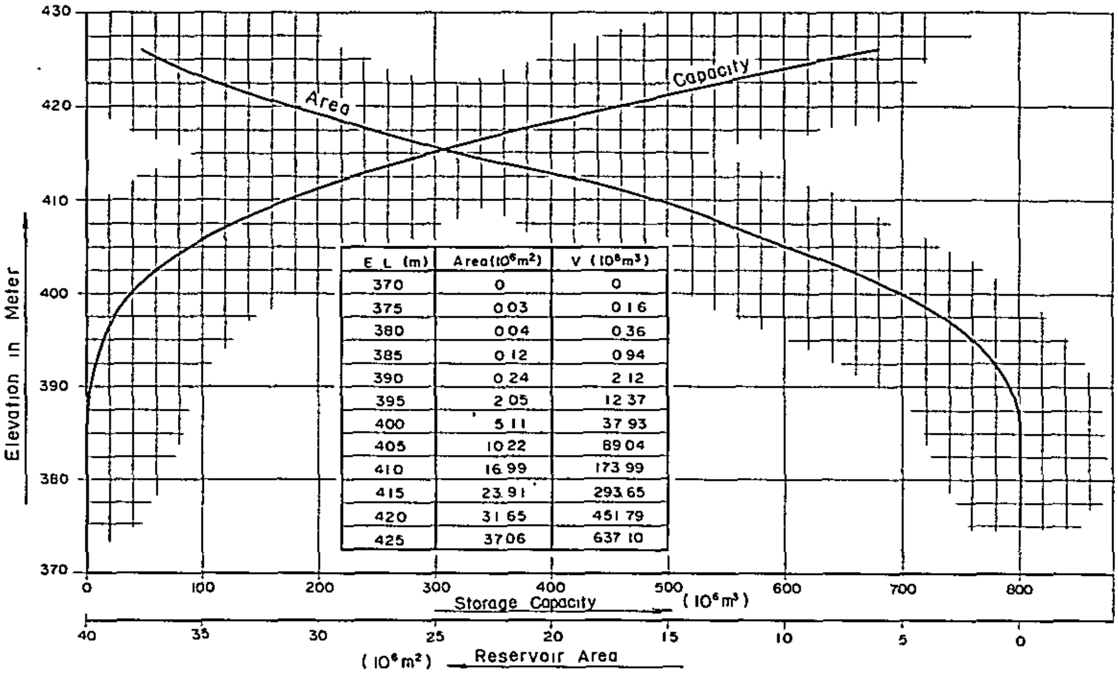
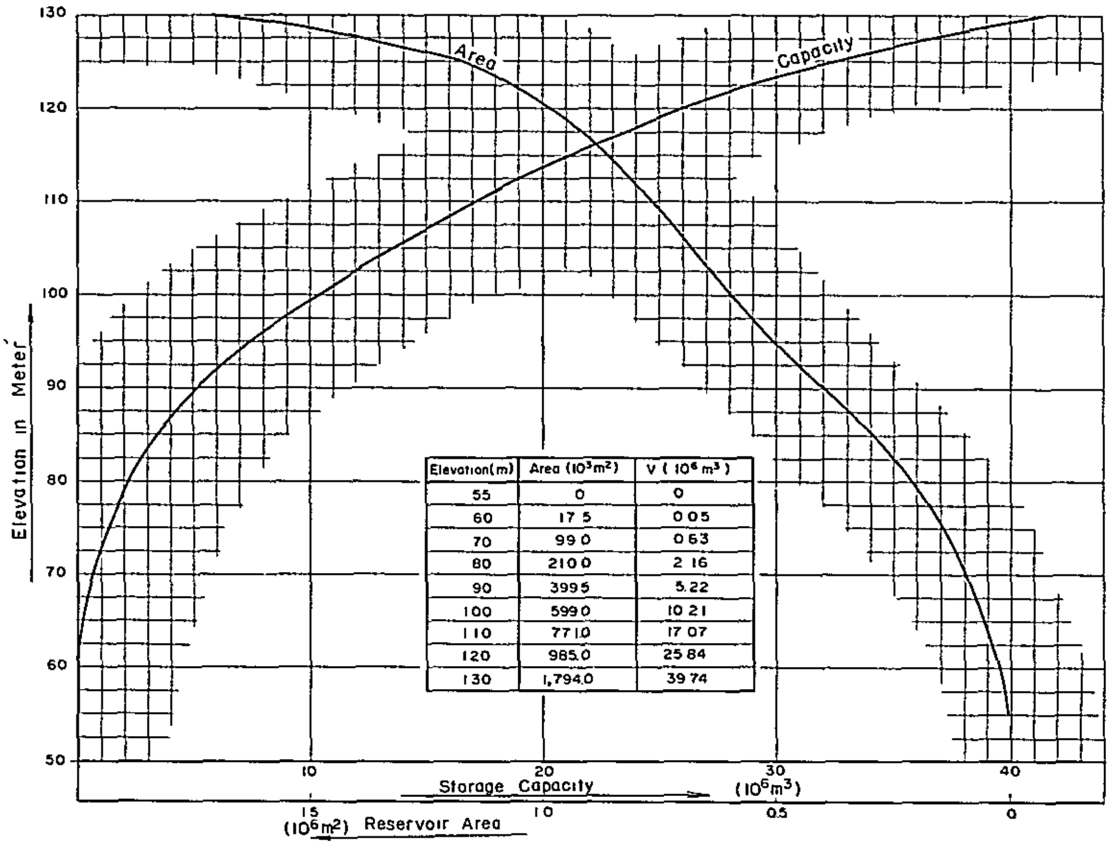


Fig 6-2 Area Capacity Curves for the Khlong Pun Reservoir



E L (m)	Area(10^6m^2)	V (10^6m^3)
370	0	0
375	0.03	0.16
380	0.04	0.36
385	0.12	0.94
390	0.24	2.12
395	2.05	12.37
400	5.11	37.93
405	10.22	89.04
410	16.99	173.99
415	23.91	293.65
420	31.65	451.79
425	37.06	637.10

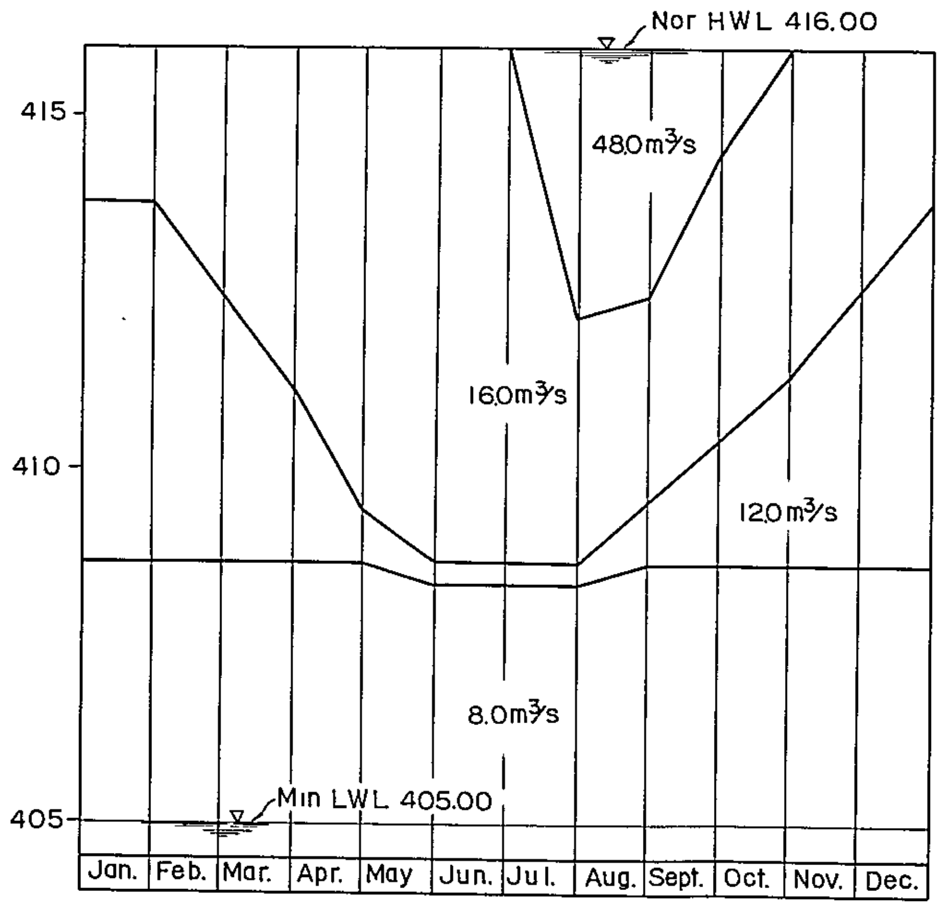
Fig 6-3 Area Capacity Curves for the Khlong Tha Dan Reservoir



Elevation(m)	Area (10^3m^2)	V (10^6m^3)
55	0	0
60	17.5	0.05
70	99.0	0.63
80	210.0	2.16
90	399.5	5.22
100	599.0	10.21
110	771.0	17.07
120	985.0	25.84
130	1,794.0	39.74

Fig 6-4 Tentative Operation Rule of the Khlong Pun Reservoir

Month	V_u		V_M		V_L		Month
	m	$10^6 m^3$	m	$10^6 m^3$	m	$10^6 m^3$	
Jan.	416.0	229	413.8	168	408.7	60	Jan.
Feb.	416.0	229	412.5	136	408.7	60	Feb.
Mar.	416.0	229	411.1	107	408.7	60	Mar.
Apr.	416.0	229	409.4	75	408.7	60	Apr.
May	416.0	229	408.7	60	408.4	55	May
Jun.	416.0	229	408.7	60	408.4	55	Jun.
Jul.	412.2	130	408.7	60	408.4	55	Jul.
Aug.	412.5	136	409.6	78	408.7	60	Aug.
Sept.	414.5	184	410.5	94	408.7	60	Sept.
Oct.	416.0	229	411.3	111	408.7	60	Oct.
Nov.	416.0	229	412.7	140	408.7	60	Nov.
Dec.	416.0	229	413.8	168	408.7	60	Dec.



Symbols (Unit: m^3/Sec - month)

V_{n-1}	:	Storage at the end of previous month
V_n	:	Storage at the end of current month
V_u	:	Standard upper limit of storage
V_M	:	Standard middle limit of storage
V_L	:	Standard lower limit of storage
V_{max}	:	Maximum storage
V_{min}	:	Minimum storage
f_n	:	Overflow in current month
g_n	:	Inflow in current month
Q_n	:	Discharge for power in current month
Q_{max}	:	Maximum discharge for power
Q_u	:	Standard (upper) discharge for power
Q_M	:	Standard (middle) discharge for power
Q_L	:	Minimum discharge for power
E_V	:	Evaporation loss in current month

Constants (Unit: m^3/Sec - month)

Q_{max} = 48.0
Q_u = 16.0
Q_M = 12.0
Q_L = 8.0

Basic Formula

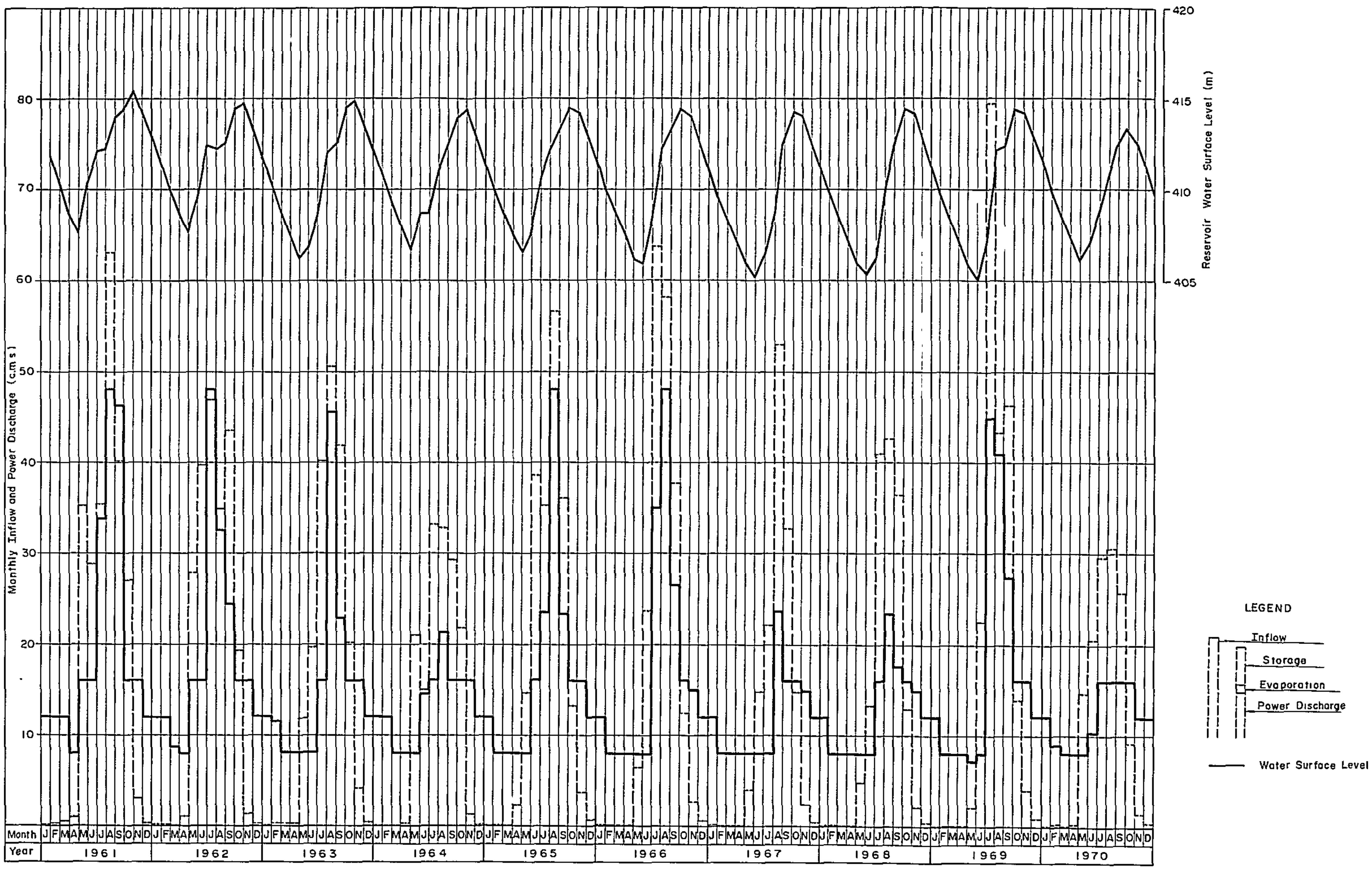
$$V_{max} \geqq V_{n-1} + g_n - Q_n - EV \Longrightarrow V_n = V_{n-1} + g_n - Q_n - EV$$

$$V_{n-1} + g_n - Q_n - EV > V_{max} \Longrightarrow \begin{cases} V_n = V_{n-1} + g_n - Q_n - EV - f_n \\ f_n = V_{n-1} + g_n - Q_n - EV - V_{max} \end{cases}$$

Operation Rule

1. $V_{n-1} + g_n > V_u$
   (1) $V_{n-1} + g_u - V_n \geqq Q_{max}$ $\Longrightarrow Q_n = Q_{max}$
   (2) $Q_{max} > V_{n-1} + g_n - V_n \geqq Q_u$ $\Longrightarrow Q_n = V_{n-1} + g_n - V_n - EV$
   (3) $Q_u > V_{n-1} + g_n - V_u$ $\Longrightarrow Q_n = Q_u$
2. $V_u \geqq V_{n-1} + g_n > V_M$ $\Longrightarrow Q_n = Q_u$
3. $V_M \geqq V_{n-1} + g_n > V_L$ $\Longrightarrow Q_n = Q_M$
4. $V_L \geqq V_{n-1} + g_n$
   (1) $V_{n-1} + g_n - V_{min} \geqq Q_L$ $\Longrightarrow Q_n = Q_L$
   (2) $Q_L > V_n + g_n - V_{min}$ $\Longrightarrow Q_n = V_{n-1} + g_n - V_{min} - EV$

Fig 6-5 Monthly Inflow, Power Discharge and Reservoir Water Surface Level



Regarding the high water level of the reservoir, since the investigation of the damsite was made only by a light airplane and by a short reconnaissance on earth, it cannot be taken as a sufficiently accurate marginal water level of the reservoir. The definite and appropriate level of the high water would be decided after obtaining a clear grasp of the topographical and geological conditions of the damsite and the surrounding area, through accurate mapping, exploratory drillings and adits which will be made in the future. Also, for a more distinct determination of the reservoir capacity, it is desirable to get more and better hydrologic data.

As for the Khlong Tha Dan Regulating Pond, the storage capacity was calculated to be 7×10^6 cu.m for the purpose of holding the water for pumping-up for the pumped-storage power station and for the regulation of the discharge used for peak power generation at the Khlong Pun Power Station. In order to obtain this capacity, the high water surface level of the Khlong Tha Dan Regulating Pond would be at 110 m and the available drawdown would be 10 m (See Fig 6-3).

6) Reservoir Operation and Energy Production

In order to study the runoff regulation by the Khlong Pun Reservoir, a reservoir operation rule was tentatively established for the plan of development of conventional type. The basic principle of operation rule is, firstly, that inflow in the rainy season should be impounded for discharge in the dry season, secondly, that inflow in wet years should be impounded for discharge in dry years, and thirdly, that runoff should be regulated in the most effective manner to secure as large an amount of available discharge as possible. The rule of operation established based on the principle is indicated in Fig. 6-4. Power generation, available discharge and energy production were calculated assuming that the power station was efficiently operated for the past runoffs at the damsite based on the reservoir operation rules. In the future, when actual operation of the reservoir is to be carried out, it would be necessary to make further studies in order to establish more detailed rule. The anticipated quantity of water discharge for power generation, overflow from the spillway of dam and the reservoir water level when power generation is performed, based on the reservoir operation rule are shown in Fig. 6-5.

In carrying out the abovementioned calculations, evaporation from the reservoir surface was taken into consideration. The evaporation was taken to be 600 mm annually as described in Chapter 5.1. Seasonal variation in evaporation, however, was not considered.

The expected monthly energy productions based on a conventional reservoir operation for the 10-years period from 1961 through 1970 were computed, using the available discharge calculated. The results are shown in Tables 6-3 and 6-4. The average annual energy production calculated on the basis of such conventional reservoir operation rule utilizing the past ten years would be as follows:

Khlong Pun Power Station	332.1 x 10^6 kWh
Khlong Tha Dan Power Station	69.5 x 10^6 kWh

As for the energy of the pumped-storage power station, as described in Chapter 4, it was assumed that the annual operating time would be 1,500 hours in consideration of the future balance of demand and supply as shown below.

Khlong Pun Pumped-Storage Power Station	600 x 10^6 kWh
Sam Sip Pumped-Storage Power Station	600 x 10^6 kWh

Operation rule for the pumped-storage development will be studied in detail in the feasibility investigations.

Due considerations would be also given to the operation rule in future for the sake of preserving the beautiful scenery fo waterfalls.

7) Installed Capacity and Number of Units

Maximum installed capacity of a power station must be determined to meet the shortage in capacity of the power system in the most economical manner. For this purpose, a study was made of the positions to be occupied by the power stations of the Khlong Tha Dan Project in the future demand and supply balance of this power system. As a result, the maximum installed capacity were determined assuming the plant factor of the generating facilities on general peak hours to be about 30%.

For the case of pumped-storage power generation, it was assumed that the target time for development would be in the latter half of the 1970s and the installed capacity was taken to be 400 MW (see Chap. 4, Demand and Supply Balance).

The installed capacities calculated for each power station are indicated in Table 6-5.

As for the intake water surface level of the Khlong Pun Power Station, the standard water level of the reservoir was adopted, which is one-third of draw-down depth lower than normal high water level. The tailwater level, in the case of a

Table 6-3 Monthly Energy Production of the Khlong Pun P.S

(Unit : 10^3kWh)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1961	21,880.2	19,665.7	21,657.2	13,905.9	28,823.9	28,105.4	61,506.8	87,660.2	71,240.0	29,410.7	28,451.5	21,955.8	434,263.3
1962	21,851.3	19,636.9	15,347.7	13,904.5	28,771.5	28,072.9	87,446.8	59,240.0	43,416.5	29,375.2	28,369.3	21,876.5	397,309.1
1963	21,763.1	18,780.4	14,364.0	13,841.9	14,287.4	13,883.0	28,942.4	82,792.4	40,597.6	29,379.1	28,391.3	21,907.6	328,930.2
1964	21,798.0	20,281.4	14,382.8	13,859.5	14,341.8	25,168.3	28,906.9	38,870.6	28,291.8	29,332.7	28,337.7	21,848.4	285,419.9
1965	21,732.0	13,071.2	14,363.0	13,847.6	14,312.6	27,903.6	42,683.9	87,553.5	41,293.6	29,344.6	28,318.6	21,843.9	356,268.1
1966	21,730.5	13,024.4	14,362.0	13,837.5	14,260.3	13,851.9	63,266.8	87,580.1	47,058.6	29,340.6	26,548.9	21,836.5	366,698.1
1967	21,720.9	13,018.1	14,354.1	13,829.9	14,241.0	13,790.7	14,332.4	42,962.5	28,308.1	29,330.7	26,233.6	21,835.8	253,957.8
1968	21,719.4	13,481.2	14,351.7	13,827.5	14,242.5	13,789.7	28,730.0	42,410.1	30,908.0	29,343.6	26,379.3	21,835.0	271,018.0
1969	21,718.7	13,016.3	14,352.2	13,827.5	12,581.0	13,809.8	81,008.4	74,368.7	48,374.6	29,348.5	28,327.2	21,853.5	372,586.4
1970	21,740.9	14,601.8	14,363.0	13,839.9	14,295.3	17,996.2	28,883.1	29,067.9	28,268.9	29,223.0	21,134.2	21,729.8	255,144.0
Total	217,656.0	158,577.4	171,897.7	138,521.7	170,157.3	196,371.5	465,707.5	632,506.0	407,756.7	293,428.7	270,491.6	218,522.8	3,321,594.9
Mean	21,765.60	15,857.74	15,189.77	13,852.17	17,015.73	19,637.15	46,570.75	63,250.6	40,775.67	29,342.87	27,049.16	21,852.28	332,159.49

Table 6-4 Monthly Energy Production of the Khlong Tha Dan P.S

(Unit : 10^3kWh)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1961	3,705.1	3,351.7	3,719.6	2,419.5	6,042.4	5,450.1	10,953.3	14,820.5	12,954.0	5,623.5	4,837.0	3,707.0	77,583.7
1962	3,705.1	3,348.8	2,627.9	2,425.0	5,797.1	5,799.7	14,820.5	10,545.8	8,198.8	5,368.3	4,783.6	3,705.1	71,125.7
1963	3,705.1	3,219.9	2,478.8	2,401.2	2,794.3	2,767.9	5,618.4	14,820.5	7,671.8	5,395.5	4,871.5	3,709.1	59,454.0
1964	3,705.1	3,467.1	2,470.9	2,399.7	3,100.8	4,544.4	5,386.6	7,039.9	5,195.0	5,447.7	4,781.0	3,705.1	51,243.3
1965	3,705.1	2,242.6	[illegible],472.1	2,464.1	2,888.9	5,761.7	7,771.6	14,820.5	7,594.2	5,165.5	4,857.9	3,720.6	63,464.8
1966	3,709.6	2,233.3	2,471.8	2,391.3	2,618.0	2,895.6	12,260.7	14,820.5	8,615.9	5,139.0	4,527.8	3,718.4	65,401.9
1967	3,708.3	2,232.1	2,470.1	2,392.3	2,532.6	2,610.1	2,550.5	8,435.5	5,305.2	5,274.1	4,464.5	3,713.5	45,628.8
1968	3,707.1	2,313.4	2,471.3	2,393.8	2,562.5	2,562.9	5,643.8	7,982.2	5,860.3	5,154.9	4,479.7	3,710.4	48,842.3
1969	3,706.8	2,231.4	2,470.5	2,390.4	2,186.1	2,855.3	14,820.5	13,394.6	9.125.8	5,188.9	4,866.1	3,725.2	66,961.6
1970	3,705.1	2,505.2	2,472.4	2,398.0	2,877.3	3,498.3	5,268.2	5,307.7	5,077.9	5,031.6	3,588.6	3,708.7	45,439.0
Total	37,062.4	27,145.5	26,125.4	24,075.3	33,400.0	38,476.0	[illegible],094.1	111,987.7	75,598.9	52,729.0	46,057.7	37,123.1	595,145.1
Mean	3,706.24	2,714.55	2,612.54	2,407.53	3,340.00	3,847.60	8,509.41	11,198.77	7,559.89	5,272.90	4,605.77	3,712.31	59,514.51

pumped-storage power station, was taken to be the median water level of the Khlong Tha Dan Regulating Pond, while for a conventional type of power station, the estimated water level at the power station outlet was taken as the tailwater level.

For the Sam Sip Pumped-Storage Power Station, the intake water surface level was taken to be the standard water level of the reservoir, while the tailwater level was taken at the median water level of the Khlong Tha Dan Regulating Pond.

The intake water surface level of the Khlong Tha Dan Power Station was taken to be the median water level of the regulating pond, while the tailwater surface level was taken to be the estimated water level at the power station outlet.

Further, in the case the layout was that of an conventional hydroelectric plant, the powerhouses were considered as outdoor types. When the layout was for pumped-storage power stations, the powerhouses were taken to be underground types.

In the case of a pumped-storage power station, it would generally be of advantage economically to use reversible pump-turbines. With present technology, for the effective head of about 300 m, the manufacturing limits for the capacity of one unit is around 250 to 300 MW. Therefore, for this Project, in the case of a pumped-storage power station, 2 units of 200-MW reversible pump-turbines were considered.

When the Khlong Pun Power Station is to be an conventional type of Plan C, it was considered that there should be 2 units each of turbines (high-head Francis) and generators (60 MW), since the installed capacity would be relatively large.

In case of plan of pumped-storage development, the Khlong Tha Dan Power Station would have an installed capacity of 20 MW which is relatively small, and 1 unit each of turbine (Francis) and generator was considered.

The transmission line would be of 115 kV and/or 230 kV.

Table 6-5 Installed Capacity of Power Plant

Item \ Power Station \ Plan		Plan of Development of Conventional Type (C)	Plan of Development of Pumped-Storage, Recirculation-Type (R)			Plan of Development of Pumped-Storage, Multi-Use Type (M)	
		Khlong Pun P.S.	Khlong Pun P.S.	Khlong Tha Dan P.S.	Sam Sip P.S.	Khlong Pun P.S.	Khlong Tha Dan P.S.
Discharge	m^3/sec	48.0	48.0	48.0	134.0	160.0	48.0
Intake Water Surface Level	m	416.0	416.0	110.0	475.0	416.0	110.0
Tailwater Level	m	110.0	110.0	45.0	110.0	110.0	45.0
Effective Head	m	295.0	295.0	50.0	360.0	295.0	50.0
Out Put	MW	120.0	120.0	20.0	400.0	400.0	20.0
Type of Power Station		Conventional and Outdoor	Conventional and Outdoor	Conventional and Outdoor	Pumping-up and Underground	Pumping-up and Underground	Conventional and Outdoor

CHAPTER 7

DESCRIPTION OF PRELIMINARY LAYOUT

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CHAPTER 7. DESCRIPTION OF PRELIMINARY LAYOUT

7.1 Khlong Pun Dam and Power Station

In determination of the type of the Khlong Pun Dam, studies were made for a rockfill type and a concrete gravity type using a 1/10,000-scale topographical map.

As for the damsite, the immediate upstream of the Heo Narok Waterfall was selected, because of the topographical conditions. The results of the study showed a rockfill type to be slightly more economical, but since the Project would be in a national park area and in consideration of scenic beauty, and to arrive at a conservative estimate of construction cost, a concrete gravity dam was adopted.

In regard to the type of the dam and its design, it should be necessary for studies to be made upon obtaining technical data hereafter through preparation of detailed topographical maps based on boring surveys of the dam axis, investigations of quantities and qualities of the various materials to be used, etc., further giving consideration to harmony with the natural surroundings.

The particulars of this concrete gravity dam would be crest length of 590 m, crest width of 4 m, slope of 1 : 0.72 and crest elevation of 420 m. The concrete volume of the dam is estimated to be 234,000 cu.m.

It was decided to provide the spillway in the river bed section. For design flood discharge, since measured records were insufficient, the Rational Formula was tentatively applied and a figure of 1,200 cu.m/sec was adopted. The gates for the spillway were selected to be 3 tainter gates.

The Khlong Pun Reservoir would have a high water surface level of 416 m and cover an area of approximately 25 sq.km. The total storage capacity and effective storage capacity would be 318 x 10^6 cu.m and 229 x 10^6 cu.m respectively. The catchment area would be 292.8 sq.km. including the catchment area of the adjacent Khan Basin.

The diversion tunnel would be provided on the right bank of the dam with a length of 330 m and inner diameter of 7.0 m.

The powerhouse intake would be provided approximately 300 m upstream of the diversion tunnel and the water taken in would be conveyed to a surge tank by a pressure tunnel. The pressure tunnel would be 2,000 m long with a diameter of 6.5 m in Plan M, and 2,000 m long with a diameter of 5.0 m in Plan R and Plan C. The size of the surge tank would be inner diameter of 20 m for Plan M, and 15.0 m for Plan R and Plan C, the surge tank being a simple type respectively. Between the surge tank and the power station there would be a penstock which would be 520 m long with inner diameter of 4.5 m-3.0 m in Plan M, and 650 m long with an inner diameter of 4.0 m-1.8 m in Plan R and Plan C.

The powerhouse for Plan M would be an underground type with dimensions of 80 m x 49 m x 49 m. In Plan C and Plan R, it would be an outdoor type, the dimensions of which would be 37 m x 16.5 m x 38.5 m.

Regarding the tailrace, in Plan M, the water used in power generation would be conveyed to the outlet by a tunnel of 125 m long diameter with 6.5 m and discharged into the Khlong Tha Dan River. In Plan C and Plan R, since the powerhouse would be an outdoor type, the water used in power generation would immediately be discharged into the Khlong Tha Dan River.

As for an outdoor switchyard, since there is no suitable location on the right bank in any of the Plan C, R and M, it would be provided on the left bank side. The space required would be 50 m x 20 m.

With respect to intake dams of rivulets in the Khan Basin, concrete intake dams would be provided at one place on the upstream part of the Huai Som Phung Yai River and two places on the upstream part of the Huai Nang Rong River. An intake tunnel to the Khlong Pun Reservoir has its total length 14.5 km. The inner diameters of the intake tunnels would be 2.9 m - 3.7 m.

There seems to be an insufficient quantity of construction materials for a dam at the Khlong Tha Dan River. For this reason, in the case of plan to construct a concrete dam, it would be necessary to produce aggregate from quarried material. Also, if the plan is for construction of a rockfill dam, the rock material and filter material would need to be obtained from quarried material. As a result of surface geological survey, the suitable areas for quarry would be Areas A, B and C (see Chapter 9).

As for the layout and construction cost, see Fig. 7-1, 7-2, 7-3 and Table 7-1.

7.2 Khlong Tha Dan Dam and Power Station

The dam would be a concrete gravity type with a crest length of 290 m, crest width of 4 m, slope of 1 : 0.72 and crest elevation of 114 m. The concrete volume of the main body of the dam is estimated to be approximately 167,000 cu.m.

The crest elevation of the spillway would be 101 m and three spillway tainter gates would be provided.

The catchment area of the reservoir would be 309.2 sq.km and the reservoir area at high water surface level of 110 m would be 0.77 sq.km. The total storage capacity would be 17×10^6 cu.m and the effective storage capacity at drawdown of 10 m would be 7×10^6 cu.m.

The diversion channel during construction would be provided by coffering one-half of the present river using the remaining half as the diversion channel.

The powerhouse intake would be provided close to the dam and water would be conveyed to a surge tank by a headrace 2,050 m long with diameter 5.0 m.

The surge tank would be a differential type with an inner diameter of 11.0 m. From the surge tank a penstock 305 m long would be constructed to the powerhouse.

The powerhouse would be a outdoor type with the size of the building being 25 m x 19 m x 28 m.

The outdoor switchyard would be provided adjacent to the powerhouse. The area required would be 20 m x 50 m.

Although there are small amounts of sand and gravel at the Khlong Tha Dan River, they are insufficient quantities to be used as aggregate for the dam. Therefore, aggregates would need to be produced from a quarry, and as a quarry site Area D is thought to be suitable.

As for the layout and construction cost, see Fig. 7-1, 7-2, 7-3 and Table 7-1.

7.3 Sam Sip Reservoir and Pumping-up Station

Because of dense forests, the topography of the surrounding area of the proposed reservoir could not be adequately grasped in field reconnaissance and the plan was studied based on a 1/10,000-scale topographical map. The type of the dam would be rockfill, with a main dam and two dikes to be constructed. The length of the main dam would be approximately 320 m and that of the dikes 370 m with the total volume of the three being approximately 450,000 cu.m. Inside the reservoir, in order to obtain the necessary effective capacity, approximately 900,000 cu.m of excavation was planned. The bedrock at first glance appears to be good so that facing of the surface was not considered, and the construction cost was estimated without considering the facing. However, as a result of geological survey in feasibility investigation in future, facing might be found to be necessary.

The diversion channel would be provided at the left bank side of the main dam with diversion made by a tunnel of approximately 200 m.

The intake would be provided at the right bank side of the main dam and would be a morning glory type. The distance between the intake and the surge tank would be connected by a pressure tunnel 1,200 m long with an inner diameter of 5.5 m. The surge tank would be a water chamber type. From the surge tank to the powerhouse, two penstock lines 640 m in length with inner diameters of 3.8 - 2.8 m would be provided.

The powerhouse would be an underground type, the dimensions being 22m x 50 m x 85 m.

Regarding the tailrace, the water used in power generation would be discharged into the Khlong Tha Dan Reservoir by a tailrace tunnel 340 m long with an inner diameter of 4.0 m - 5.5 m.

The material excavated from the bottom of the reservoir would be adequate for use and the dikes.

As for the layout and construction cost, see Fig. 7-1, 7-2, 7-3 and Table 7-1.

7.4 Transmission Facilities

In the event of Plan C, which is an conventional hydroelectric development plan, the power generated at the Khlong Pun Power Station would be transmitted to Prachin Buri where it would be interconnected with the existing 115-kV transmission system.

In the event of Plan R, a pumped-storage power development plan, the distance between the Sam Sip Power Station and Bangkok would be connected by a 230-kV transmission line. The Khlong Pun Power Station and the Khlong Tha Dan Power Station would be connected by a 115-kV transmission line in this case. The two transmission lines would be connected using a 230-kV/115-kV interconnection trasformer.

In the event of Plan M, a pumped-storage power development plan, it would be necees-sary to provide a 230-kV transmission line between the Khlong Pun Power Station and Bangkok in order to receive the electric power necessary for pumped storage from Bangkok and to transmit the power generated back to Bangkok. The power generated at the Khlong Tha Dan Power Station would be transmitted to the Khlong Pun Power Station by a 230-kV line.

Photo. 7–1 Khlong Pun Damsite, Looking Downstream

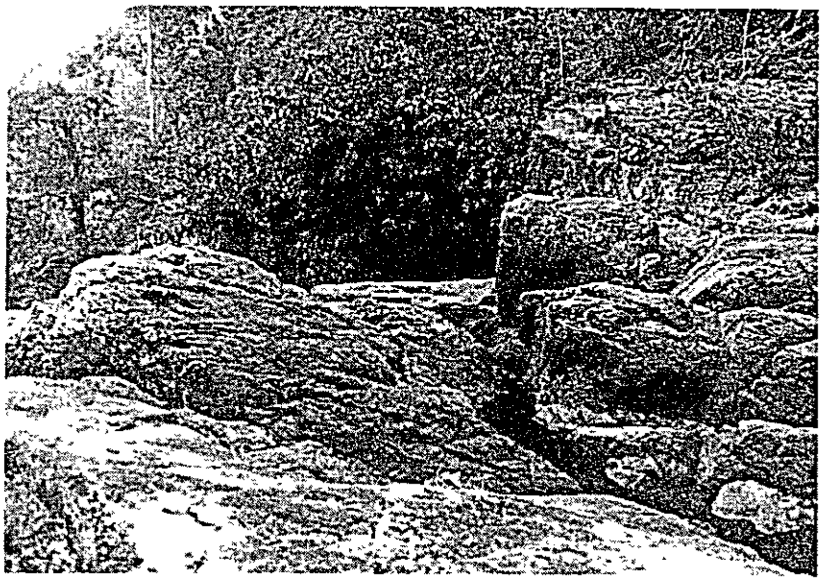
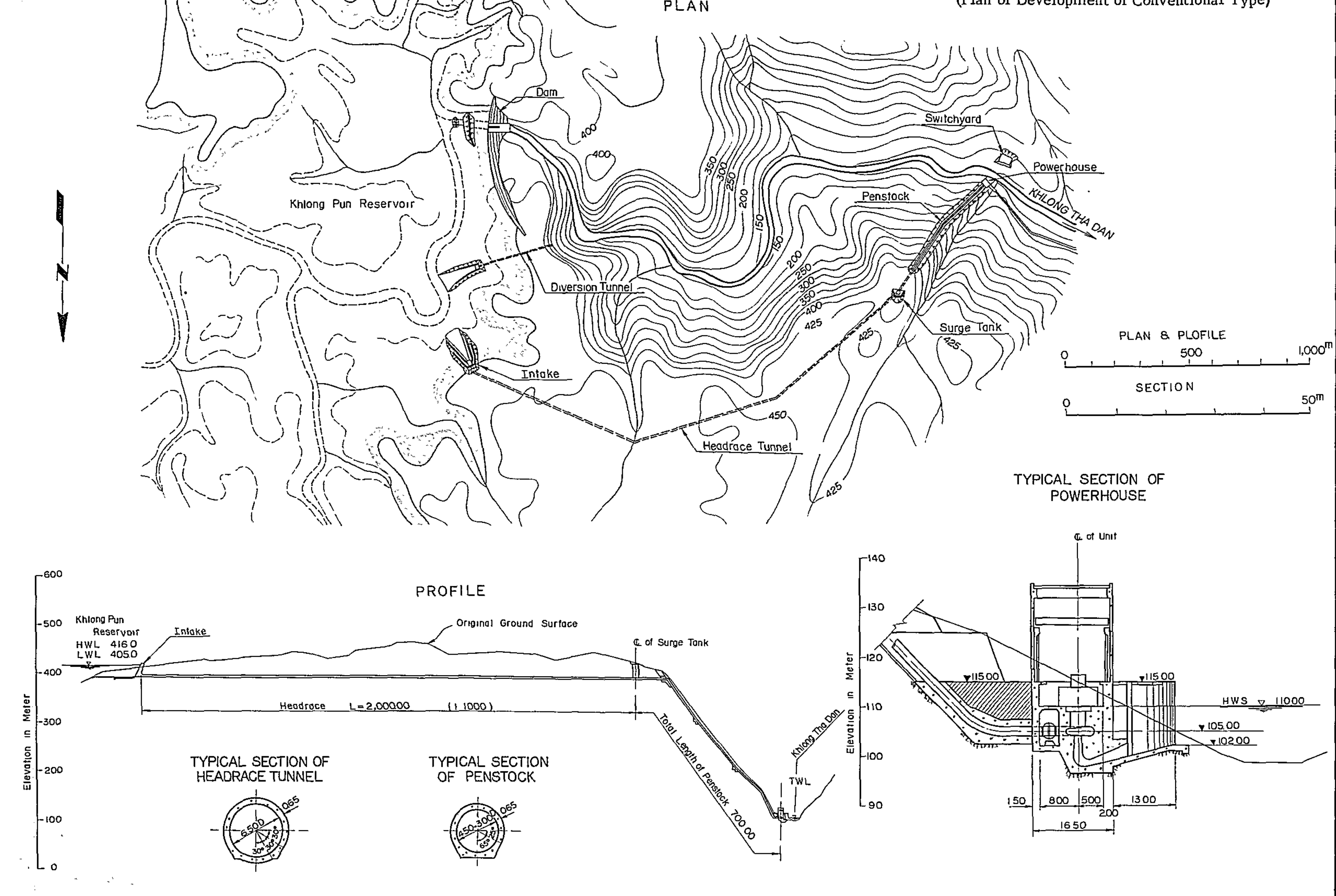


Photo. 7–2 Bedrock of Rhyolite near Kholong Pun Damsite

Fig 7-1 Alternative Plan, Plan C
(Plan of Development of Conventional Type)



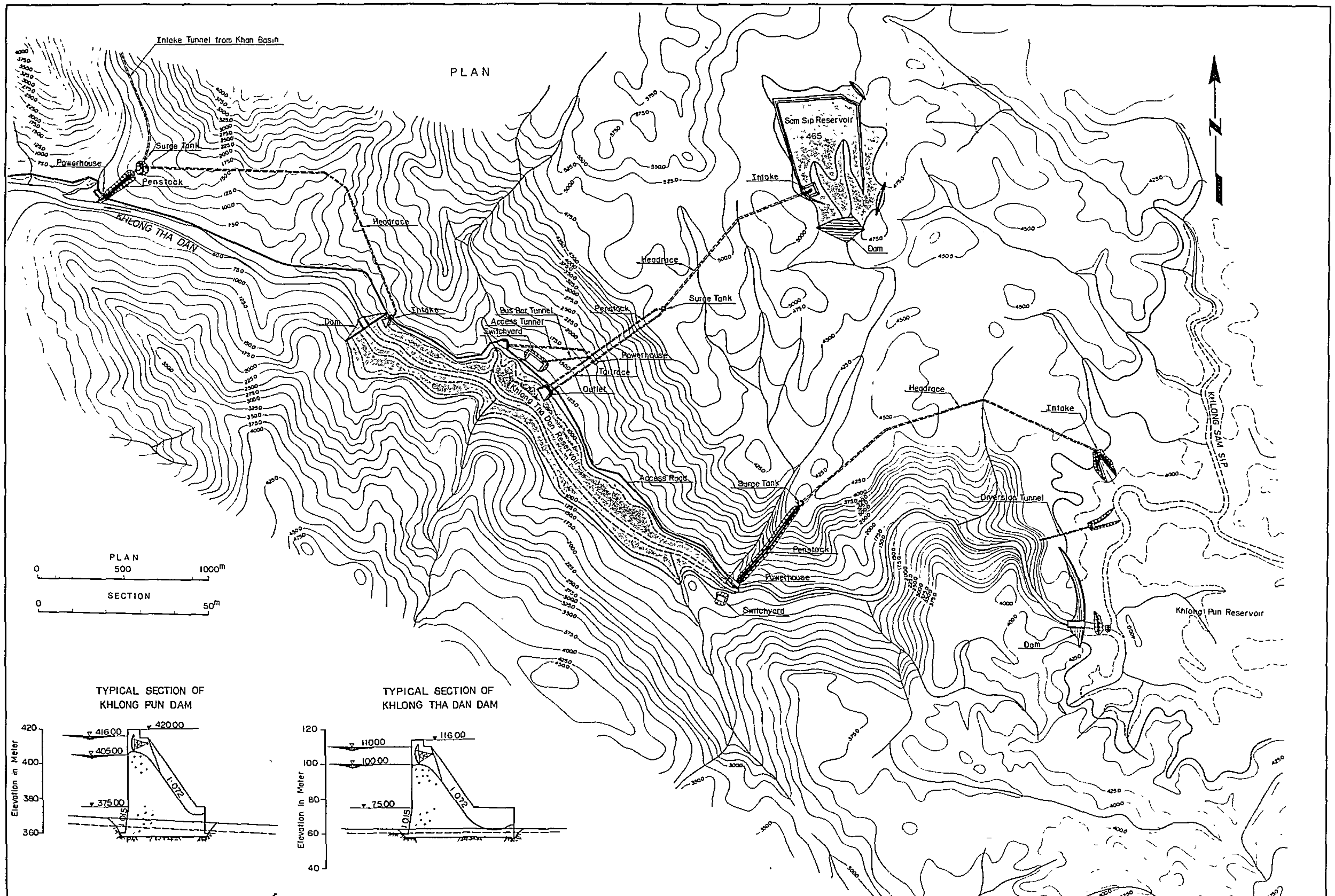


Fig 7-2(1) Alternative Plan, Plan R (Plan of Development of Pumped-Storage, Recirculating Type)

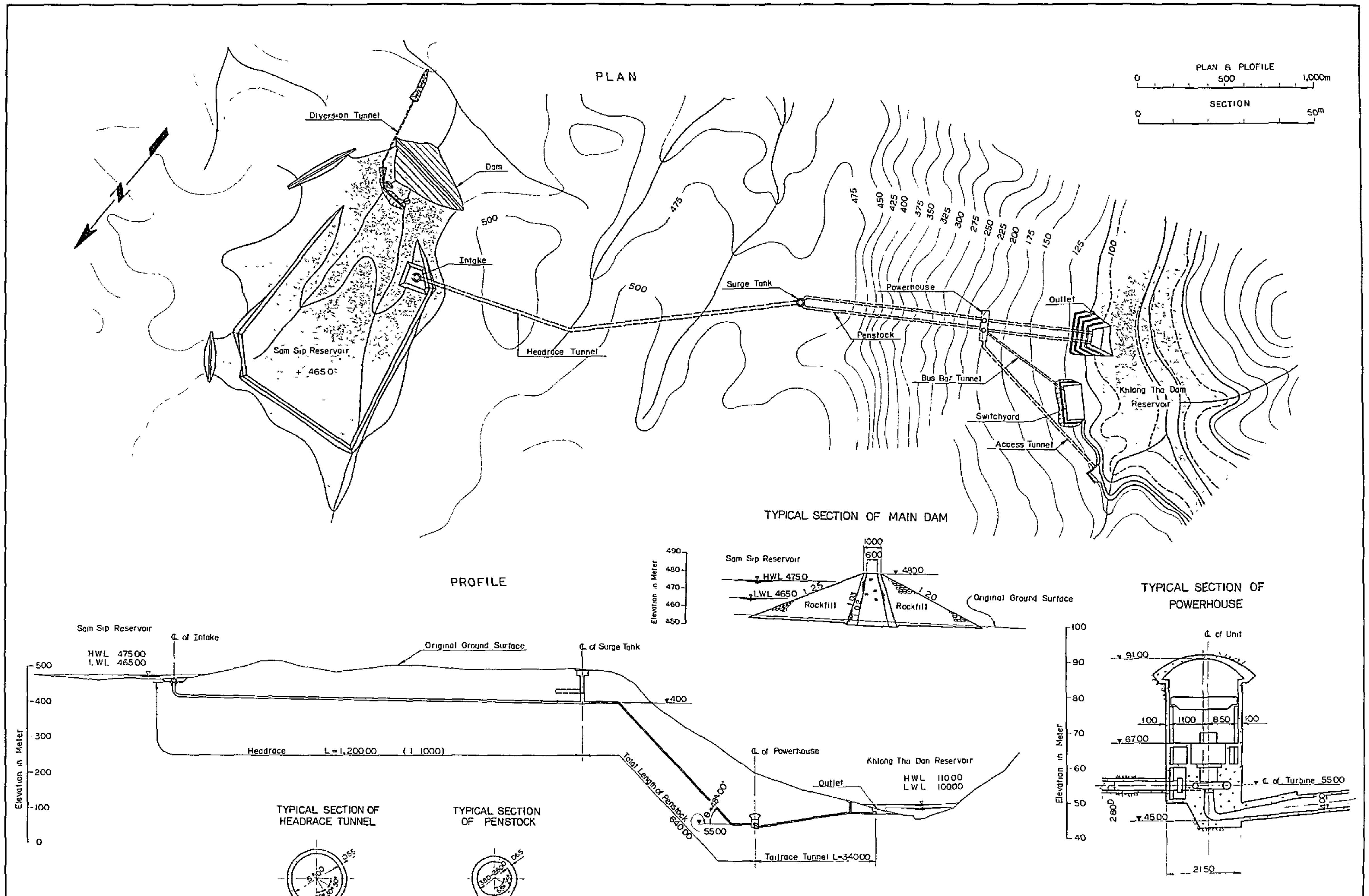


Fig
7-2(2) Alternative Plan, Plan R
(Layout of Sam Sip Reservoir and Power Station)

Fig 7-3 Alternative Plan, Plan M (Plan of Development of Pumped-Storage, Multi-Use Type)

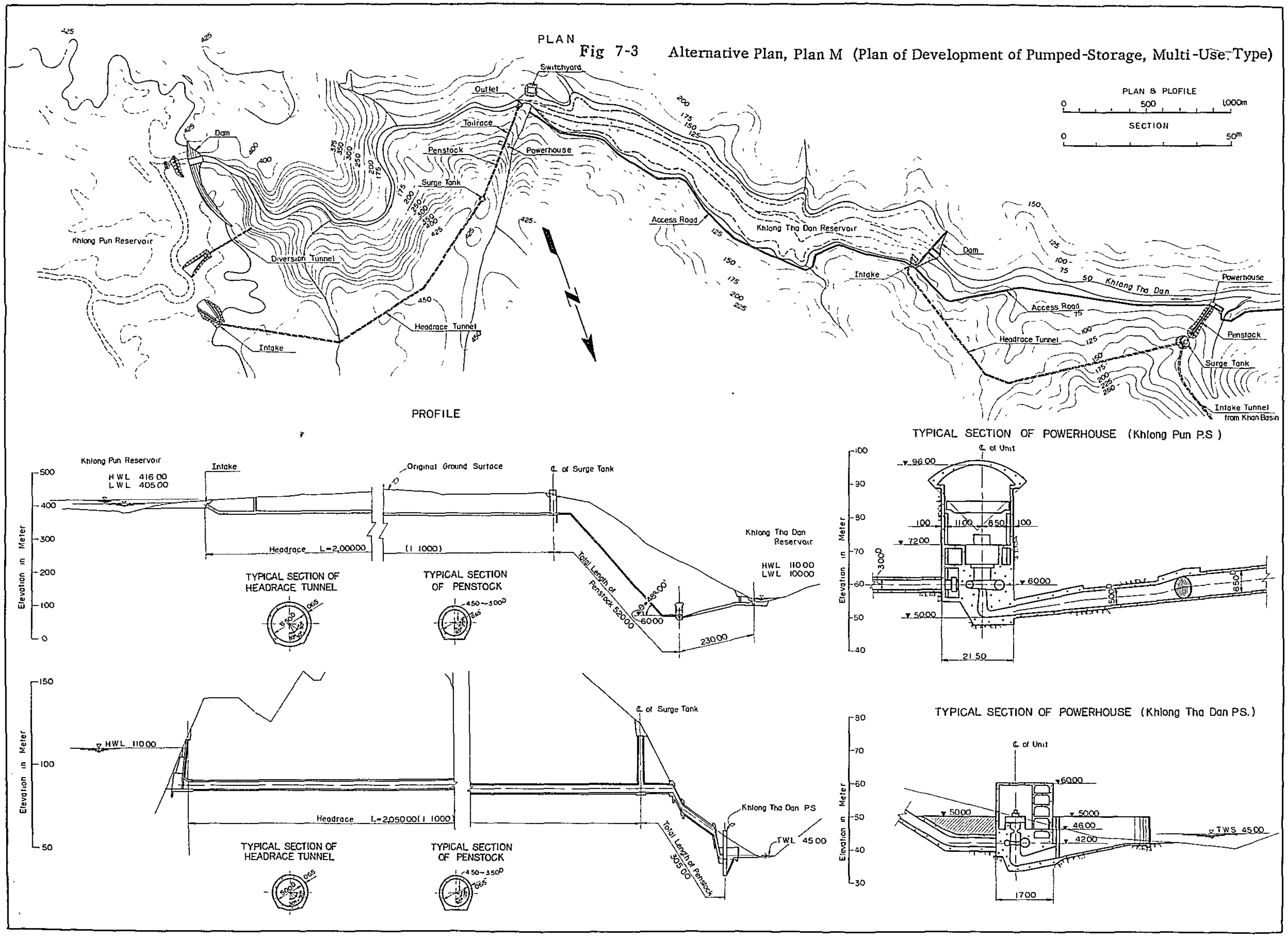


Table 7-1 Estimated Construction Cost of Alternative Plans (Unit : 10^6 Baht)

Item / Power Station / Plan	Plan of Development of Conventional Type (C)	Plan of Development of Pumped-Storage, Recirculating Type (R)				Plan of Development of Pumped-Storage, Multi-Use Type (M)		
	Khlong Pun P.S	Khlong Pun	Khlong Tha Dan	Pumping-up	Total	Khlong Pun	Khlong Tha Dan	Total
1. Generating Facilities	737.2	737.2	310.1	661.0	1,708.3	1,128.8	314.9	1,443.7
(1) Civil Works	581.5	581.5	237.1	308.0	1,126.6	758.0	237.1	995.1
Access Road	57.0	57.0	12.9	3.7	73.6	57.0	12.9	69.9
Dam	167.7	167.7	96.5	69.9	334.1	167.7	96.5	264.2
Waterway	266.8	266.8	80.6	129.0	476.4	368.6	80.6	449.2
Power House	16.1	16.1	16.1	36.5	97.7	65.7	16.1	81.8
Contingencies	73.9	73.9	31.0	49.9	144.8	99.0	31.0	130.0
(2) Hydraulic Equipments	54.9	54.9	34.7	94.2	183.8	107.2	34.7	141.9
Gates	7.5	7.5	5.7	1.5	14.7	8.9	5.7	14.6
Penstocks	15.8	15.8	8.3	39.6	63.7	36.0	8.3	44.3
Others	2.0	2.0	2.0	1.3	5.3	3.0	2.0	5.0
Installation Cost	14.8	14.8	9.5	30.9	55.2	30.9	9.5	40.4
Import Duties	7.6	7.6	4.7	12.7	25.0	14.4	4.7	19.1
Contingencies	7.2	7.2	4.5	8.2	19.9	14.0	4.5	18.5
(3) Electrical Equipments	100.8	100.8	38.3	258.8	397.9	263.6	43.1	306.7
Turbines	23.1	23.1	9.6	54.9	87.6	60.4	9.6	70.0
Generators	24.2	24.2	8.8	54.9	87.9	60.4	8.8	69.2
Transformers	7.7	7.7	1.6	31.9	41.2	25.3	2.2	27.5
Others	11.5	11.5	5.5	22.2	39.2	20.3	8.2	28.5
Installation Cost	13.0	13.0	4.7	41.5	59.2	42.9	5.2	48.1
Import Duties	16.5	16.5	6.3	41.1	63.9	41.7	7.1	14.6
Contingencies	4.8	4.8	1.8	12.3	18.9	12.6	2.0	
2. Transmission Line	10.1	10.1	2.9	104.5	117.5	72.7	4.1	76.8
Transmission Line, Substation, Communication System and Import Duties	9.6	9.6	2.8	99.5	111.9	69.2	3.9	73.1
Contingencies	0.5	0.5	0.1	5.0	5.6	3.5	0.2	3.7
3. Engineering Fee	37.3	37.3	15.7	38.3	91.3	60.0	16.0	76.0
4. Administration Cost	29.8	29.8	12.5	30.6	72.9	48.1	12.8	60.9
5. Interest during Construction	58.6	58.6	24.8	60.6	144.0	94.4	25.2	119.6
Total	873.0	873.0	366.0	895.0	2,134.0	1,404.0	373.0	1,777.0

CHAPTER 8

ECONOMIC EVALUATION

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CHAPTER 8. ECONOMIC EVALUATION

8.1 Salable Energy and Energy Cost

The salable energy at the sending end of the Khlong Tha Dan Project is indicated in Table 8-3 (1), (2). It was assumed that this energy production would all be used effectively immediately from the start of operation. The transmission loss from power station to primary substation on the outskirts of Bangkok is estimated to be 3%.

The construction cost of the Khlong Tha Dan Project are as shown in Tables 8-3 (1), (2). Assuming interest to be 6% per annum for both domestic and foreign currency, the average annual equivalent cost over a 50-year period of analysis was determined, adding the annual cost of operation, maintenance and replacement of facilities.

In this case, the taxes and levies are not taken into consideration. Further, in the case of pumped-storage power generation the cost of power for pumping up water will be additional cost. The unit energy cost in this case was assumed to be 0.108 ฿/kWh taking the cost of additional operation of thermal power, namely the fuel cost.

The annual cost as obtained above divided by the salable energy gives the average energy cost delivered at substation. This is indicated in Table 8-3 (1), (2).

8.2 Comparison with Alternative Power Source

The economic evaluation of a project is generally obtained by comparison with a practicable alternative power source. However, as the capacity and capability of a project differs with each hydroelectric power station, for prectical purposes it is almost impossible to find just an alternative facility equivalent in output and energy production. And even if such an alternative source is found, it is extremely inconvenient when deciding the priority among the number of hydroelectric projects conceivable. Therefore, for this Project, the method was adopted of selecting a thermal plant as a basis which is looked upon as hereafter comprising the mainstream of development.

In this case, the No. 3 and No. 4 units (300 MW each) of South Bangkok Thermal Power Station, which are considered to occupy a major position in the electric power system of the 1970s, are selected, based upon which the following evaluation was made. The features of this standard thermal power plant are given in Tables 8-1 and 8-2.

Table 8-1 General Features of Alternative Thermal Power Plant and Construction Cost

	Unit	Figure
Installed Capacity	MW	600
Unit Capacity x Number of Unit	MW x Unit	300 x 2
Annual Capacity Factor	%	80
Thermal Efficiency at Sending End	%	36 (0.24 l/kWh)
Annual Energy Supply	x 10^6kWh	4,200
Fuel (Oil)	x 10^6liters	1,000
*Construction Cost	x 10^6 ฿	1,750

*Source : NEA Electric Power in Thailand 1969

Table 8-2 Annual Cost of Alternative Thermal Power Plant (Unit : 10^3Baht)

	Fixed Cost	Variable Cost	Remarks
1. Interest & Depreciation	127,200		Capital Recovery Factor (0.07265)
2. Operation and Maintenance	35,100	7,000	
Labour Costs	3,600		120mm x 30,000฿
Repair Expenses	28,000	7,000	Construction Cost x 2%
Miscellaneous Expenses	3,500		Construction Cost x0.2%
3. Administration Costs	2,800	560	O&M Cost x 8%
4. Fuel Cost		(350,560) 455,000	(0.35)฿ / ℓ x 1,000x10^6 ℓ 0.455
5. Total	165,100	(357,560) 462,560	
6. Annual Costs at Sending End			
Power Cost (฿/kw)	275		
Energy Cost (฿/kwh)		(0.085) 0.110	

Note :

(1) Interest Rate 6 %
Serviceable Years 30 years

(2) Figures in Parentheses exclude import duty.

8.2.1 Unit Benefit

The benefits of a hydroelectric power station is measured by the cost per kW and kWh of the basic thermal power station. The annual cost of the thermal plant considered as a basis will be as follows:

kW cost = ₿275

kWh cost = ₿0.085

Therefore, the unit benefits will be respectively as follows:

kW benefit	275 x 1.15 = ₿316
kWh benefit	₿0.11

The coefficient 1.15 used in obtaining the above kW benefit is a kW correction factor, which is for gaining the same reliability in consideration of the fact that thermal power stations have higher rates of fault than hydroelectric power stations and have long periods of forced outages.

8.2.2 Project Justification

Using the various numerical values stated in the preceding 8.2.1, with the analysis period being 50 years, the annual cost and annual benefit are calculated as indicated in Table 8-3 (1), (2).

The annual cost (C) of conventional development plan, Plan C, will be ₿64.5 x 10^6 while the annual benefit (B) will be ₿72.2 x 10^6. Therefore, the ratio of annual benefit and annual cost is 1.12 and the surplus benefit (B-C) will be ₿7.7 x 10^6. Further, the salable energy cost is ₿0.20 per kWh while the salable power cost is ₿7,500 per kW.

The annual cost (C) of plan of development, Plan R, is ₿253.9 x 10^6 while the annual benefit (B) is ₿271.3 x 10^6. Therefore, the ratio of annual benefit and annual cost will be 1.07, while the surplus benefit (B-C) is ₿17.4 x 10^6. Further, the salable energy cost is ₿0.26 per kWh while the salable power cost is ₿4.074 per kW.

The annual cost of plan of development, Plan M, is ₿226.6 x 10^6 while the annual benefit (B) is ₿234.5 x 10^6. Therefore, the ratio of annual benefit and annual cost (B/C) is 1.03, while surplus benefit (B-C) is ₿7.9 x 10^6. Further, the salable energy cost is ₿0.24 per kWh and salable power cost is per ₿4.362 kW.

These three selected plans of development all have ratio between annual benefit and annual cost (B/C) of more than 1 while surplus benefits are also on the plus side. Therefore,

Table 8-3 (1) Annual Cost and Annual Benefit (Plan of Development of Conventional Type)

Plan / Power Station / Item	A	B			C
	Khlong Pun P.S	Khlong Pun P.S	Khlong Tha Dan P.S	Total	Khlong Pun P.S
Construction Cost (10^6฿)	537.4	537.4	522.9	1,060.3	873.0
Generating Facilities	525.1	525.1	519.3	1,044.4	861.2
Transmission Line	12.3	12.3	3.6	15.9	11.8
Annual Cost (C) (10^6฿)	39.8	39.8	38.5	78.3	64.5
Generating Facilities	38.6	38	38.2	76.8	63.3
Transmission Line	1.2	1.2	0.3	1.5	1.2
Annual Benefit (B) = (1) + (2) (10^6฿)	44.5	44.5	14.6	59.1	72.2
Dependable Out-Put (Gen. End) : (kW)	75,000	75,000	25,000	100,000	120,000
Effective Out-Put (Rec. End) : kW	72,750	72,750	24,250	97,000	116,400
(1) Benefit of kW (10^6฿)	23.0	23.0	7.7	30.7	36.8
Annual Energy (Gen. End) : 10^6kWh	201.6	201.6	64.9	266.5	332.1
Effective Energy (Rec. End) : 10^6kWh	195.5	195.5	63.0	258.5	322.1
(2) Benefit of kWh (10^6฿)	21.5	21.5	6.9	28.4	35.4
Benefit-Cost Ratio	1.12			0.75	1.12
Surplus Benefit (10^6฿)	4.7			-19.2	7.7
Salable Energy Cost (Rec. End) ฿/kWh	0.20			0.30	0.20
Power Cost (Rec. End) ฿/kW	7,387			16,931	7,500

(This plan was selected.)

Table 8-3 (2) Annual Cost and Annual Benefit (Selected Plan of Development)

Item / Power Station / Plan	C : Plan of Development of Conventional Type	R : Plan of Development of Pumped-Storage, Recirculating Type					M : Plan of Development of Pumped Storage, Multi-Use Type		
	Khlong Pun P.S	Khlong Pun P.S	Khlong Tha Dan P.S	Sub-Total	Pumping Up P.S	Total	Khlong Pun P.S	Khlong Tha Dan P.S	Total
Construction Cost (10^6฿)	873.0	873.0	366.0	1,239.0	895.0	2,134.0	1,404.0	373.0	1,777.0
Generating Facilities	861.2	861.2	362.6	1,223.8	772.8	1,996.6	1,319.0	368.2	1,687.2
Transmission Line	11.8	11.8	3.4	15.2	122.2	137.4	85.0	4.8	89.8
Annual Cost (C) (10^6฿)	64.5	64.5	26.9	91.4	162.5	253.9	199.1	27.5	226.6
Generating Facilities	63.3	63.3	26.6	89.9	56.8	146.7	96.9	27.1	124.0
Transmission Line	1.2	1.2	0.3	1.5	11.4	12.9	7.9	0.4	8.3
Expenses for Pumping-Up Energy		-	-		94.3	94.3	94.3	-	94.3
Annual Benefit (B) = (1) + (2) (10^6฿)	72.2	72.2	12.5	84.7	186.6	271.3	222.0	12.5	234.5
Dependable Out-Put (Gen. End) : kW	120,000	120,000	20,000	140,000	400,000	540,000	400,000	20,000	420,000
Effective Out-Put (Rec. End) : kW	116,400	116,400	19,400	135,800	388,000	523,800	388,000	19,400	407,400
(1) Benefit of kW (10^6฿)	36.8	36.8	6.1	42.9	122.6	165.5	122.6	6.1	128.7
Annual Energy (Gen. End) : (10^6 kWh)	332.1	332.1	59.5	391.6	(600.0)	391.6 (600.0)	332.1 (600.0)	59.5	391.6 (600.0)
Effective Energy (Rec. End) : 10^6 kWh	322.1	322.1	57.7	379.8	(582.0)	379.8 (582.0)	322.1 (582.0)	57.7	379.8 (582.0)
(2) Benefit of kWh (10^6฿)	35.4	35.4	6.4	41.8	(64.0)	41.8 (64.0)	35.4 (64.0)	6.4	41.8 (64.0)
Benefit-Cost Ratio	1.12			0.93	1.15	1.07			1.03
Surplus Benefit (10^6฿)	7.7			- 6.7	24.1	17.4			7.9
Salable Energy Cost (Rec. End) (฿/kWh)	0.20			0.24	0.28	0.26			0.24
Power Cost (Rec. End) (฿/kW)	7,500			9,124	2,307	4,074			4,362

Figures in parenthese shows energy production by pumped-storage.

these development plans are thought to be economically feasible. However, which of the alternatives is to be pushed should be decided upon detailed study of future growth in power demand of Thailand, the necessity for peak power and more detailed investigations of the project features.

8.3 Other Prospecting Benefits

In the downstream area of the Khlong Tha Dan River, in the event this Project is realized, there seems to be approximately 6,400 ha of land irrigable in the dry season utilizing the water spent for power generation.

According to very rough calculations, the annual surplus benefit when the irrigation program is carried out will be 1,500 Baht/ha, while the annual benefit-annual cost ratio is calculated to be 2.5.

The effect of the Project on this agricultural aspect is described in Appendix A-2.

Also, as described in Chapter 3, the project area is located in Khao Yai National Park. Therefore, as in Japan, Europe and America, it may be possible to consider recreation benefits due to the Project. However, this is a matter outside the field of our study and cannot be elaborated in this Report.

CHAPTER 9

FUTURE INVESTIGATIONS FOR FEASIBILITY STUDY

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CHAPTER 9. FUTURE INVESTIGATIONS FOR FEASIBILITY STUDY

In order to conduct a feasibility study, it is necessary for the following to be carried out beforehand;

(1) Preparation of Topographical Maps

i) In order to ascertain the storage capacities of the Khlong Pun Reservoir and the Khlong Tha Dan Reservoir, the existing aerial survey topographical maps (1/10,000-scale, 5-m contour) should be reexamined carefully.

ii) For parts of the project area not covered by the abovementioned aerial survey topographical maps, aerial survey topographical maps of the same scale and same contour should be additionally prepared. (See Fig. 9-1)

iii) In order to improve the accuracies of structural designs and construction cost estimates, trees should be felled for better vision at the proposed sites for the structures indicated below, at the same time prepared accurate topographical maps of 1/2,000-scale, 1.0-m contour, for the area centered around these sites.

Khlong Pun Dam
Khlong Pun Waterway
Khlong Pun Power Station
Sam Sip Reservoir
Khlong Tha Dan Dam
Khlong Tha Dan Waterway
Khlong Tha Dan Power Plant
Intake Dams in Khan Basin

iv) Since there is a topography in the form of a saddle near the end of the backwater of the Khlong Pun Reservoir, it is necessary to confirm whether there will be a possibility of the water of the reservoir leaking to other basins through this point. For this purpose, preparation of topographical maps explained in ii) above and performance of drilling described in (2) below will be required.

v) The expense for the above-mentioned mapping would require roughly ฿1,600,000 if it is estimated in Japan.

(2) Geological Investigation Work

The influence of geological conditions on design of civil structures and estimate of construction costs is great. Therefore, in order to carry out a feasibility study, it is necessary to have performed the geological survey work indicated in Table 9-1 and Fig. 9-2.

The expense for the geological investigation work would require roughly ฿2,100,000 if it is estimated in Japan.

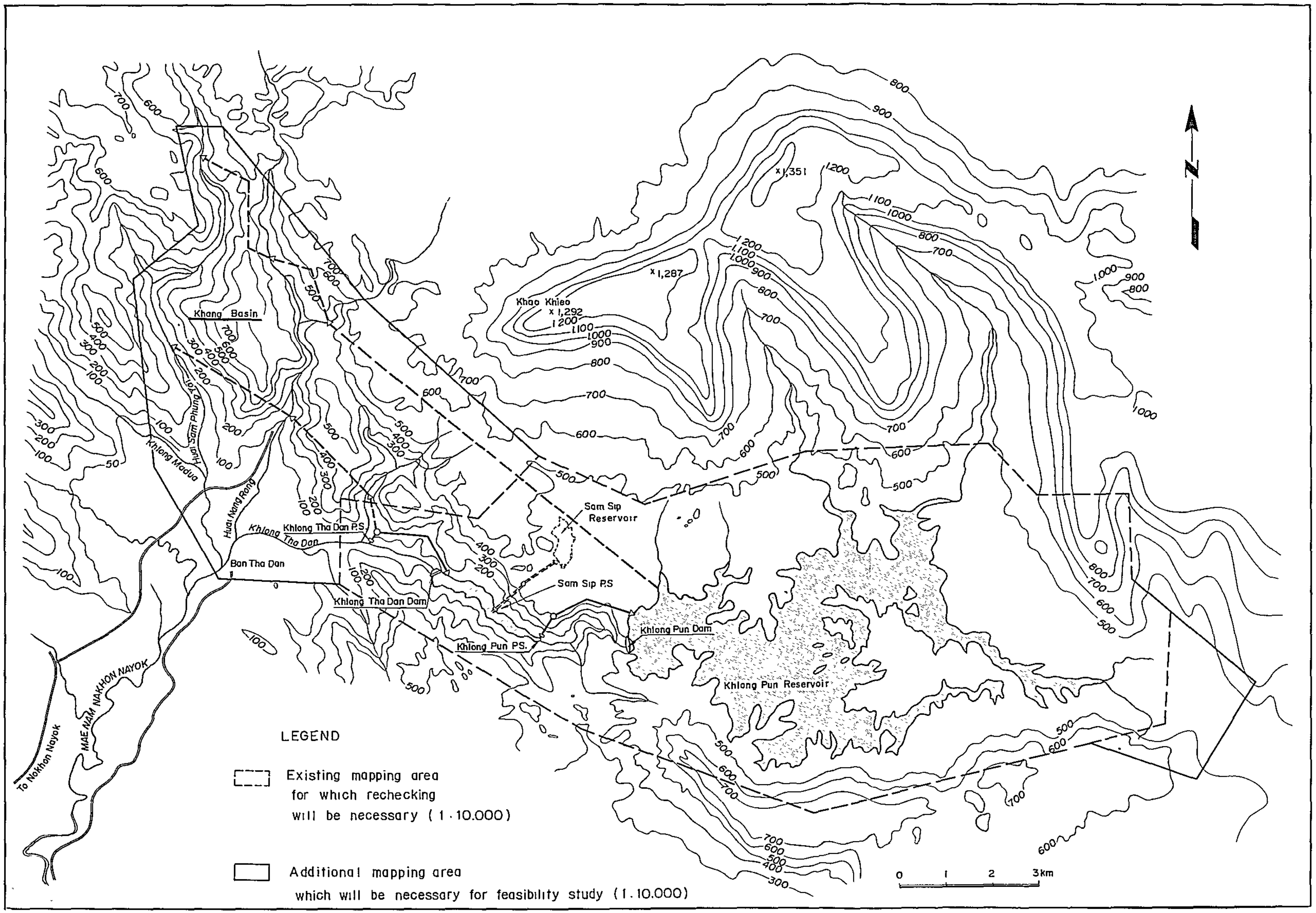
(3) Compilation of Hydrologic and Meteorological Data

As hydrologic and meteorological data are basic to water resources development, the hydrology and meteorology should be observed continuously and recorded at the two gaging stations at Ban Khlong Si Sook and at the neighborhood of the Khlong Pun damsite.

Especially, during heavy rains when floods are expected, it is desirable for observations to be made every other hour.

Hydrologic and/or meteorological data of the Nam Sai Yai Basin adjecent to the project area, and at Nakhon Nayok, Prachin Buri and Bangkok should be compiled.

Fig 9-1 Location Map of Survey Investigations for Feasibility Study



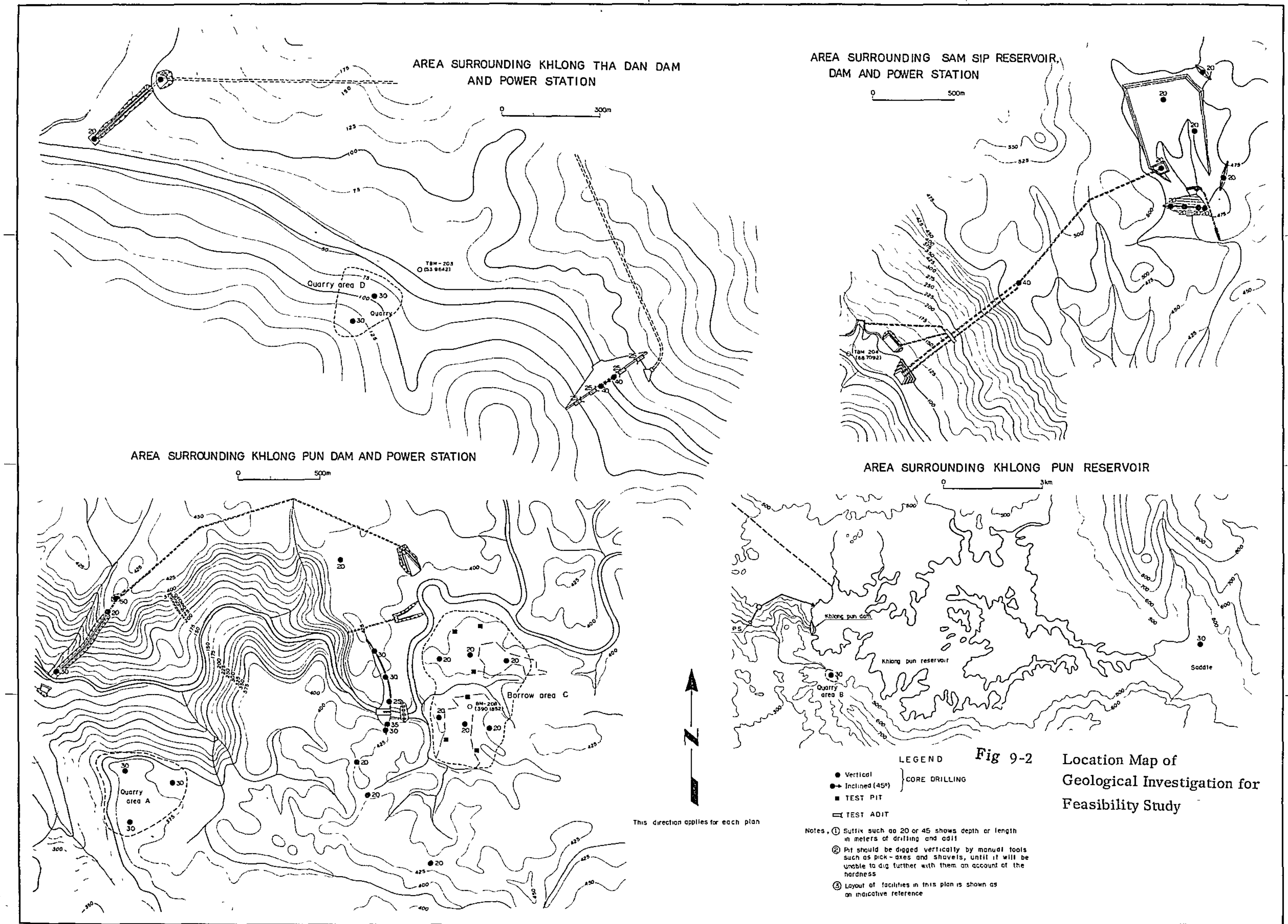


Fig 9-2 Location Map of Geological Investigation for Feasibility Study

Table 9-1 List of Geological Investigation

Khlong Pun Dam:

Location	Drilling		Pit	
	Number	Length (m)	Number	Depth
Dam	5	150		
Reservoir Rim near Dam	4	80		
Saddle near the End of Back Water	1	20		
Quarry Area, A	3	90		
Quarry Area, B	1	30		
Center of Surge Tank	1	50		
End of Penstock Tunnel	1	20		
Center of Power House	1	30		
Borrow Area, C	6	120	6	*
Total	23	590	6	

* Pits should be digged vertically by manual tools such as pick-axes and shovels, until it will be anable to dig further with them on account of the hardness.

Khlong Tha Dan Dam :

Location	Drilling		Adit	
	Number	Length (m)	Number	Length (m)
Dam (Drilling for riverbed, Adit for Abutment)	2	80	4	100
Quarry Area, D	2	60		
Center of Surge Tank	1	45		
Center of Power House	1	20		
Total	6	205	4	100

Sam Sip Reservoir :

Location	Drilling	
	Number	Length (m)
Reservoir	3	60
Dam (Main)	4	80
Dike	2	40
Center of Surge Tank	1	40
Total	10	220

APPENDIX

A – 1

A REFERENCE TO THE JONES REPORT

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A-1 A Reference to the Jones Report

In the Jones Report, a short-term forecast for the 10-year period from 1968 to 1978 and a long-term forecast to 1990 were made, but since it may be considered that the Khlong Tha Dan Project would be realized in the period from the latter part of the 1970s to the early 1980s, only the long-term forecast will be reffered to here.

As preconditions for the load forecast, the report makes a number of assumptions, the more important of which are as listed below.

1) Population growth

2) Growth of Gross National Product (GNP)

3) Continuing rate reductions

4) Future levels of investment in utility facilities

At first, the population of Thailand is estimated to have been 36 million in 1970. The increase up to the present has been at an extremely high rate, and according to statistics, a growth rate of 3.1% has been recorded since 1960. This is high enough to be second if not first among the Southeast Asian countries. The Jones Report has adopted two versions of estimated population growth. One is based on the forecast of the National Statistics Office of Thailand estimating that the growth rate will become even higher in the future (P_1 : 1970 – 1975, 3.2% ; 1975 – 1980, 3.3% ; 1980 – 1985, 3.4% ; 1985 – 1990, 3.5%) and the other that the growth rate of 3.08% in 1970 will gradually be lowered to become 2.02% in 1990 (P_2).

Secondly, a forecast of GNP were not available from Thai Government, and three estimations as indicated below were made based on the data from the staff of ECAFE.

Growth Rate 1970 – 1990

GNP_1 : Decrease from 7.3% to 5.5%

GNP_2 : Constant at 8.0% after 1974

GNP_3 : Increase from 7.3% to 9.5%

Thirdly, electricity rates in the past have been lowered roughly every two years through administrative guidance by the Thai Government, and the report assumed that this has contributed greatly to the increase in power demand. Through this continuing rate reduction, the electricity rates in Thailand which had been extremely high in the past have been lowered at least in the capital area to a level comparable to foreign countries and this has been of great help in increased activity in industry and raising of living standards. However, the electricity rates in local municipalities, in spite of the repeated reductions, are still high in many places. The report makes its forecast based on the precondition that reductions in electricity rates will continue to be made in the future and that this will work as a lasting stimulant to demand.

Lastly, although the investment rate in electric power enterprises in Thailand has been about 0.8% in the past, the report considers that this will be raised in the future to 1.1% which is comparable to the rate in the U.S.A.

Based on such assumptions the Jones Report made forecasts of power demand in 6 variations using two alternatives in regard to population increase and three alternatives for GNP. In this case, the correlation between growth rate in GNP and electirc energy production was obtained by the method described below.

When a correlation is sought between GNP per capita and kWh per capita in various countries of the world as of 1966, an extremely good correlation as shown in Fig. 4-1 is found to exist. Generally, utilizing this relationship and assuming GNP and population, the electric energy production can be obtained. However, on examination of the historical trend of the relationship between GNP per capita and kWh per capita in Thailand, it is found to be at a rate considerably steeper than the world curve and takes the form of crossing with the world curve (see Fig. A-1-1 of Appendix A-1). In the Jones Report, in making the forecast of the electric energy production, the hypothesis is that this trend which is considerably different from the world curve will continue to exist in the future. It is assumed that the above GNP-kWh relationship will be the same for all of the 6 alternative cases. The results of forecast are as given below with GNP (II)/P_1, which is more or less median and suggested to be most probable.

Total Production of Power (Billions of kWh)

	1970	1978	1990
GNP (I)/P_1	5.4	19.7	52.5
GNP (I)/P_2	5.4	20.9	54.3
GNP (II)/P_1	5.3	22.7	74.2 (13,550 MW)
GNP (II)/P_2	5.4	24.0	76.7
GNP (III)/P_1	5.3	23.2	84.2
GNP (III)/P_2	5.3	24.3	86.6

A comparison between the forecast of GNP (II)/P_1 and forecasts in the past is given in Fig. 4-2. The forecast of the Jones Report compared to a past forecast (Moulton Report) is already 55% higher in 1975 and 95% higher in 1980. In terms of growth rate, from 32.8% in 1970, there is a gradual decline becoming 18.5% in 1975, 13.3% in 1980 and 8.4% in 1990.

Fig A-1-1 Relation of GDP and Energy Generation

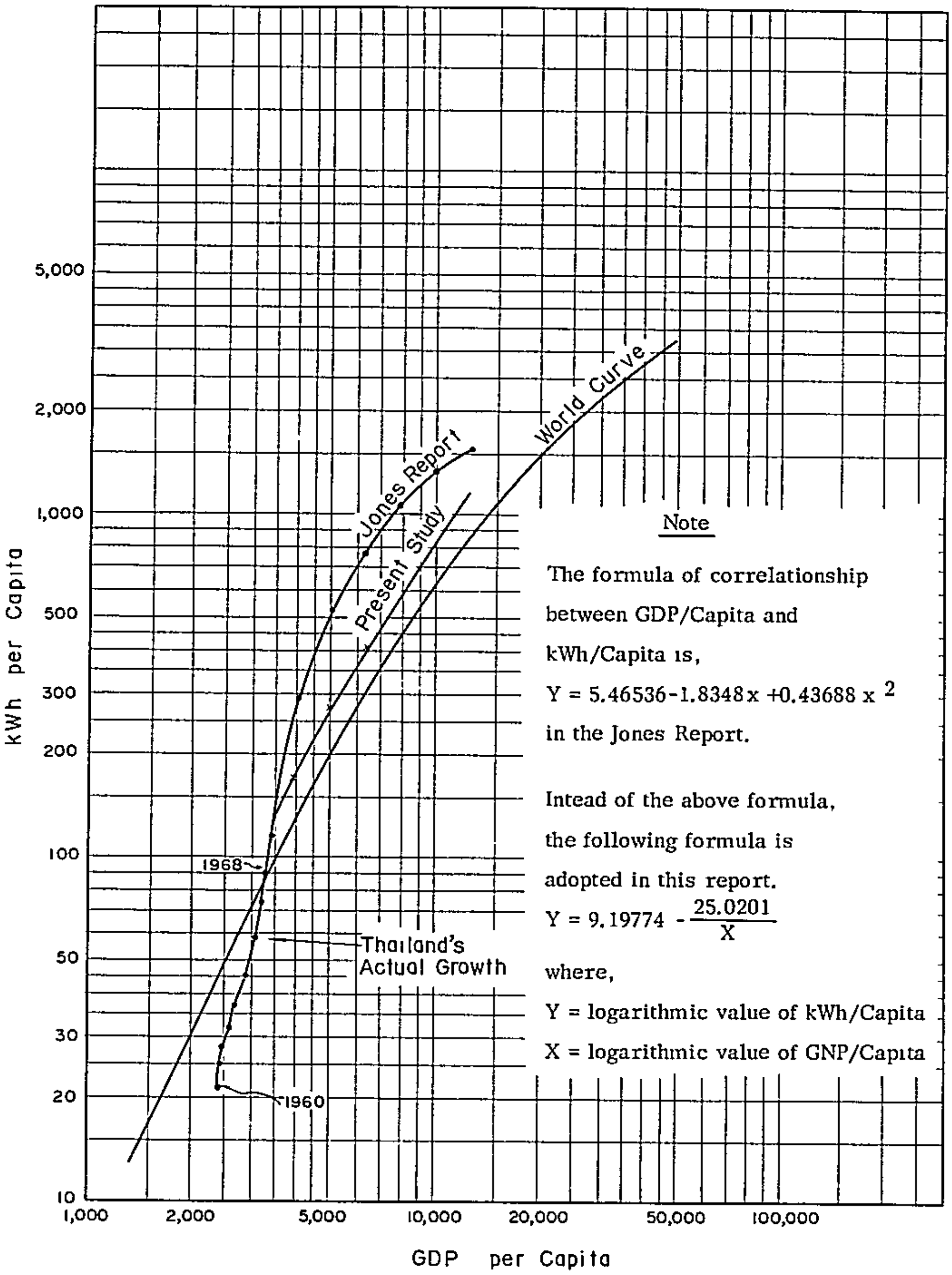

Fig A-1-2 Trend of Power Generation

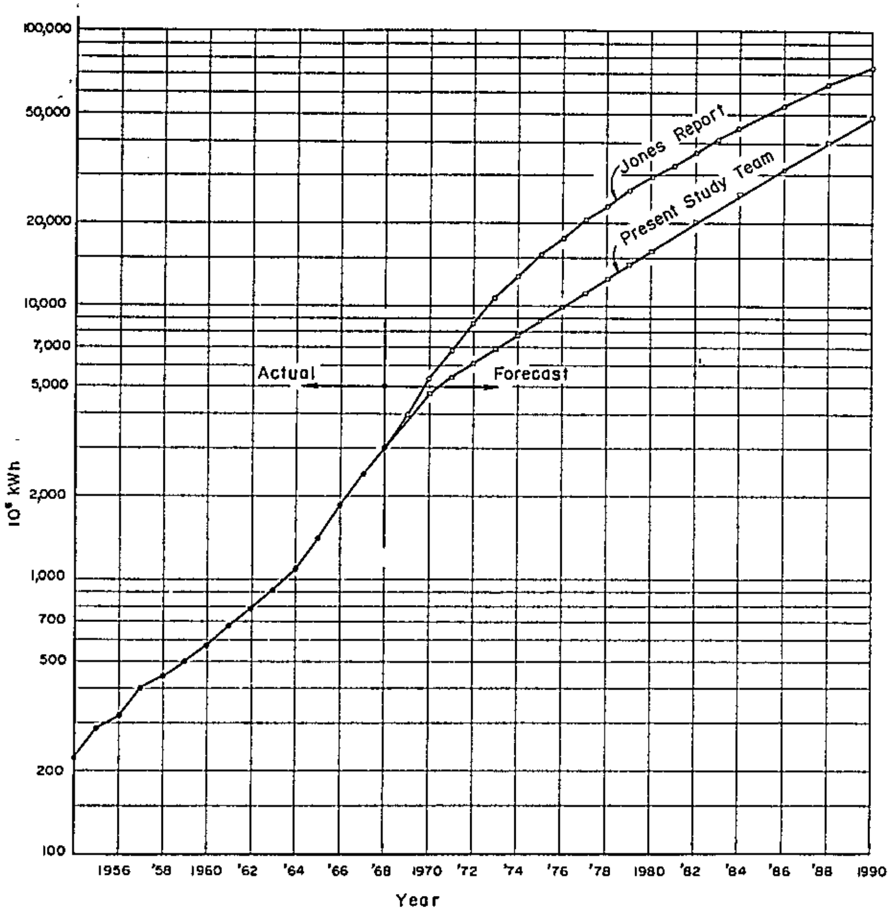

Fig A-1-3 Trend of Generation per Capita

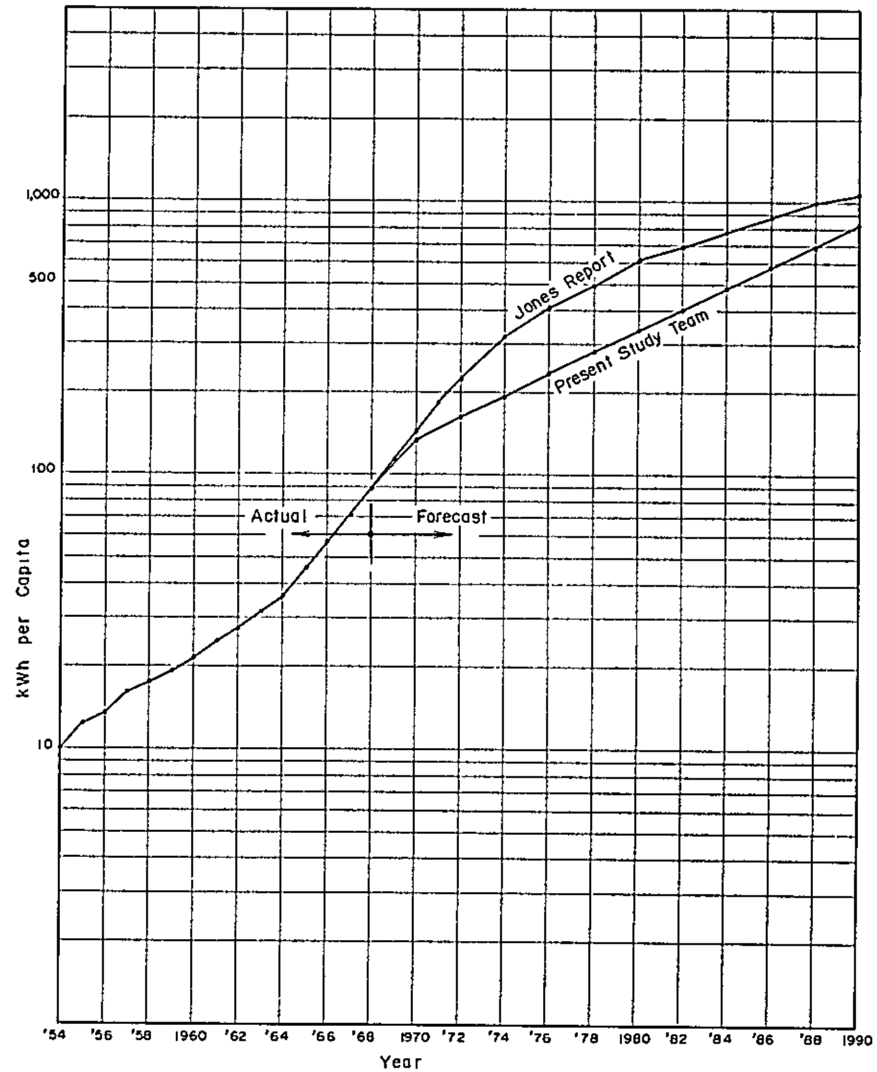

Table A-1-1 Load Forecast and Energy Balance

Unit : Million kWh

Year	Energy Demand	Average Energy Base		Firm Energy Base	
		Supply Capability	Balance	Supply Capability	Balance
1970	4,840	4,900	60	4,255	-585
71	5,440	6,380	940	5,735	295
72	6,130	6,453	323	5,795	-335
73	6,910	8,073	1,163	7,350	440
74	7,790	11,358	3,568	10,285	2,495
1975	8,790	11,358	2,568	10,285	1,495
76	9,920	13,688	3,768	12,575	2,655
77	11,190	14,848	3,658	13,635	2,445
78	12,600	18,808	6,208	17,595	4,995
79	14,180				
1980	15,920				
81	17,910				
82	20,110				
83	22,560				
84	25,300				
1985	28,320				
86	31,700				
87	35,440				
88	39,600				
89	44,200				
1990	49,300				

Table A-1-2 Load Forecast and kW Balance

Unit : MW

Year	Peak Demand	Reserve	Total Required Capacity	Dependable Capacity	Balance
1970	1,020	100	1,120	907	-213
71	1,130	110	1,240	1,122	-118
72	1,260	130	1,390	1,142	-248
73	1,405	140	1,545	1,395	-150
74	1,570	160	1,730	1,925	195
1975	1,755	180	1,935	2,035	100
76	1,965	200	2,165	2,401	236
77	2,195	220	2,395	2,617	222
78	2,450	250	2,700	3,300	600
79	2,730	270	3,000		
1980	2,960	300	3,260		
81	3,405	340	3,745		
82	3,800	380	4,180		
83	4,230	420	4,650		
84	4,720	470	5,190		
1985	5,245	520	5,765		
86	5,850	590	6,440		
87	6,520	650	7,170		
88	7,265	730	7,990		
89	8,090	810	8,900		
1990	9,000	900	9,900		

Table A-1-3 Tentative Development Plan

Fiscal Year	Power Plant	Hydro or Thermal	Installed Capacity	Total Installed Capacity	Dependable Capacity	Total Dependable Capacity	Average Energy	Total Average Energy	Firm Energy	Total Firm Energy
Up to 1970	Hydro Total	H	451	451	* 352	352	1,700	1,700	1,055	1,055
	Thermal Total	T	617	1,068	555	907	3,200	4,900	3,200	4,255
1971	Hat Yai Gas Turbine	T	15	1,083	15	922	80	4,980	80	4,335
	South Bangkok #1	T	200	1,283	200	1,122	1,400	6,380	1,400	5,735
1972	Lam Dom Noi #1, #2	H	24	1,307	20	1,142	73	6,453	60	5,795
1973	South Bangkok #2	T	200	1,505	200	1,342	1,400	7,853	1,400	7,195
	Nam Phrom	H	40	1,545	38	1,380	140	7,993	105	7,300
	Kang Krachan	H	19	1,564	* 15	1,395	* 80	8,073	* 50	7,350
1974	Surat Thani	T	30	1,594	30	1,425	185	8,258	185	7,535
	South Bangkok #3	T	300	1,894	300	1,725	2,100	10,358	2,100	9,635
	Sirikit #1, #2	H	250	2,144	* 200	1,925	1,000	11,358	650	10,285
1975	Lam Dom Noi #3	H	12	2,156	10	1,935	–	11,358	–	10,285
	Sirikit #3	H	125	2,281	* 100	2,035	–	11,358	–	10,285
1976	Sai Yai	H	70	2,351	66	2,101	230	11,588	190	10,475
	South Bangkok #4	T	300	2,651	300	2,401	2,100	13,688	2,100	12,575
1977	Quae Yai No.1 #1, #2	H	240	2,891	216	2,617	1,160	14,848	1,060	13,635
1978	Nuclear	T	500	3,391	500	3,117	3,500	18,348	3,500	17,135
	Quae Yai No. 1 #3	H	120	3,511	108	3,225	–	18,348	–	17,135
	New Mae Moh	T	75	3,586	75	3,300	460	18,808	460	17,595

* Estimated Value

A – 2

EFFECT ON THE DOWNSTREAM AREA OF THE KHLONG THA DAM PROJECT

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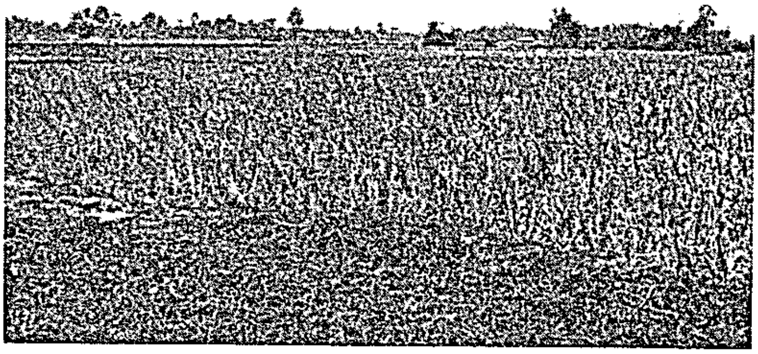

Photo. A-2-1
Existing Paddy Field
near Ban Na in dry Season.

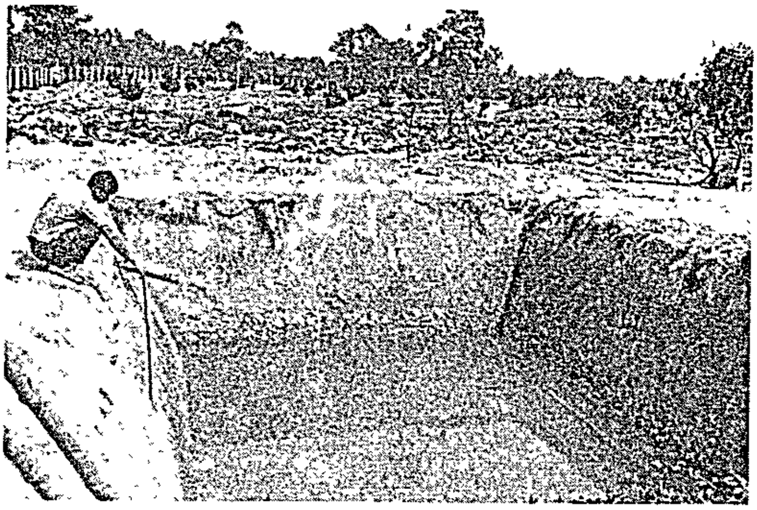

Photo A-2-2
Irrigation Pond
for Fruit Trees

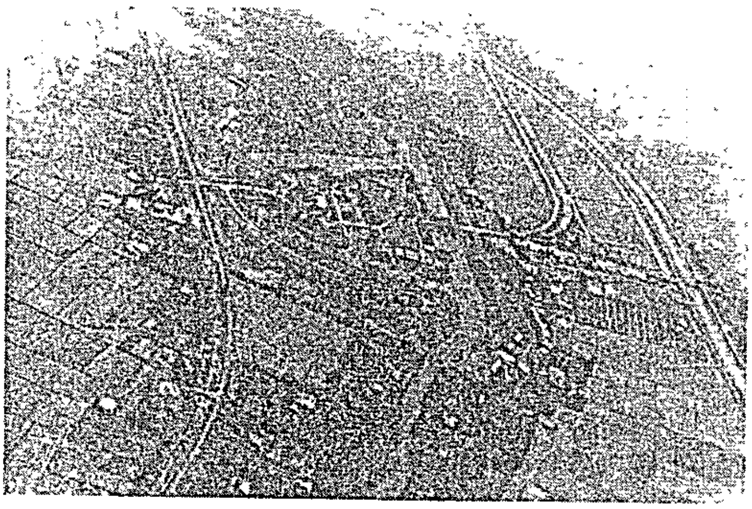

Photo. A-2-3
Intake Facility of
Nakhon Nayok Irrigation
Project

A-2 Effect on the Downstream Area of the Khlong Tha Dan Project

A-2-1 Introduction

After completion of the Khlong Tha Dan Project, the conditions of stream flow of the Khlong Tha Dan river in the downstream area will be much improved.

The average run-off in March and April has been nearly zero, but it will be increased to approximately 8.0 cu.m/sec according to a result of the study of power generation in case of Plan R or Plan M.

This study of Appendix was made very roughly assuming that the project was implemented in Plan R or Plan M where the regulated discharge for power generation could be used for the irrigation.

A-2-2 Outline of Agricultural Conditions

(1) Social Condition

Changwat Nakhon Nayok in which the project area is located belongs to the Central Region and has an area of 2,414 sq.km [1/] which is no more than approximately 0.5% of the area of entire Thailand (514,000 sq.km).

The population is approximately 153,700 [1/] (76,300 males, 77,400 females) of which the agricultural population is 113,700 [1/] or approximately 74%. The population density is 64 per sq.km [1/] and is high compared to the average for Thailand of 51 per sq.km, but is lower than the average for the Central Region of 80 per sq.km.

The irrigation project area would cover 3 districts, Amphur Ban Na, Muang and Pak Phli. The exisiting conditions of land utilization in each of these amphur is as shown in Table A-2-1. Approximately 30% of the arable land of the three districts is irrigated by the existing Nakhon Nayok Irrigation Project [2/] which was constructed by RID. Further, the cultivated area of the three districts is 453,321 rai (72,530 ha), while the number of farm households is 13,262 so that the cultivated land per household is 34 rai (5.4 ha) [3/].

1/ Statistical Yearbook 1963

2/ Nakhon Nayok Irrigation Project : The project covers an area of 574,000 rai, and there is a plan of development, the Sai Noi-Sai Yai Irrigation Project, in the east of the project.

3/ Census of Agriculture 1963 (Changwat Nakhon Nayok)

As is shown in Fig. A-2-1, Highway No. 33 goes through the middle of the Changwat. The central city, Nakhon Nayok lies on this highway. The road to Bangkok is paved all the way and it takes approximately 2 hours from Nakhon Nayok to Bangkok.

(2) Natural Condition of Agriculture

The annual mean temperature of this region according to data at Prachinburi City is 28.5°C, while the monthly average maximum temperature is 31°C (April) and the monthly average minimum temperature is 27°C (from December to January). The temperature of this region will be met the conditions to cultivate rice, vegetables and fruits throughout the year.

According to the data of Nakhon Nayok Observation Station, precipitation is an average of 2,000 mm annually with the greater part concentrated in June through October. The farmers are presently cultivating paddy rice and other crops taking advantage of this period.

The plain area, which is an alluvial land, is formed by the Prachin River and its tributaries, the Nakhon Nayok River and the Khlong Tha Dan River. The elevation of the area is approximately 40 m or lower so that it can be said a low plain land.

The mother rock of the project area is sandstone of the Mesozoic era and the soil characteristic is thought to be almost entirely sandy loam, although some silty soil can be seen at elevations of about 5 m. The topsoil is fairly deep and is considered to be favorable for cultivation of upland crops and fruit trees. The variation in underground water level is great and the water table drops to 3 - 4 m below the ground surface in the dry season and rises to the surface in the rainy season.

(3) Irrigation and Drainage Conditions

As mentioned in (1), the Nakhon Nayok Irrigation Project has already been completed on the southern part of Highway No. 33. The elevation of this project area would be below 5 m. Therefore, levees surrounding the project area have been constructed, and gates have been also provided at the outlets of drainage canals in order to protect the project area from flood in the rainy season.

Table A-2-1 Total Area of Holdings by Land Use by Amphur.

Amphur	Total Area of Holdings	Arable land						Land in tree Crops		Pasture land		Wood land		Other land	
		Land in Irrigated				Fallow and Other Arable land									
		Total		Irrigated											
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Muang	199,451	174,190	87.3	84,695	42.5	6,332	3.2	9,349	4.7	1,208	0.6	1,573	0.8	6,799	3.4
Ban Na	158,073	141,568	89.6	23,166	14.7	2,771	1.8	3,537	2.2	1,074	0.7	3,455	2.2	5,668	3.6
Pak Phli	95,797	90,594	94.6	28,723	30.0	1,051	1.1	1,217	1.3	50	0.1	772	0.8	2,113	2.2
Ongkharak	235,775	219,244	93.0	186,813	79.2	8,466	3.8	1,479	0.6	518	0.2	-	-	6,068	2.6
Total	689,096	625,596	90.8	323,397	46.9	18,620	2.7	15,582	2.3	2,850	0.4	5,800	0.8	20,648	3.0

1) Area in Rai : excluds holdings under 1 rai
2) Data Source : Census of Agriculture 1963. (Changwat NaKhon Nayok)
3) 1 rai = 40 by 40 meters = 1,600 Square meters = 0.16 hectare

However, since this project is not provided with reservoir for storing rainfall in the rainy season, the present conditions of the agriculture is that of single-crop farming of paddy rice in the rainy season.

There is almost no irrigation and drainage facilities in the northern part of Highway No. 33, which does not belong to Nakhon Nayok Irrigation Project. Particularly, on both banks of the Nakhon Nayok River, no large-scale irrigation and drainage facilities as mentioned above could be seen. In other words, between elevations of 5 m and 20 m, almost all of the arable land is regarded as an area of single-crop farming of paddy rice, while between elevations of 20 m and 40 m, however there are many fields (paddy fields and orchards) relying on rainfall on the right bank of the Nakhon Nayok River along the road which leads to Nang Rong Fall. There are found orchards of several hectares to more than 50 hectares growing durian, ranbutan, mango, etc. At these orchards, pumps and wells for irrigation are provided to cope with the dry season. The characteristics of soil is sandy and the rooting zone is deep. Since this area is near the Bangkok market, if water could be supplied throughout the year for the higher lands from EL. 20 m to EL. 40 m, it could become a promising fruit-growing district.

(4) State of Farm Management

Farm management in Amphur Muang, Ban Na and Pak Phli, except for fruit orchards in part, consists almost entirely of paddy rice cultivation utilizing rainfall in the rainy season. The scale of farm management per household of 34 rai (5.4 ha) is higher than the national average of 19 rai.

If it is broken down into classes for the three districts combined, approximately 2% are of 9.9 rai (1.6 ha) or less, 63% of 10 rai to less than 60 rai (1.6 - 9.6 ha), while approximately 22% are of 60 rai to less than 100 rai (9.6 - 16 ha) as shown in Table A-2-2.

The conditions of land tenure are indicated in Table A-2-3, which shows that for the three districts combined, land owners comprise about 70%.

The major crops, cropping areas and the amount of production around the project area are indicated in Table A-2-4. It can be seen from this that the area of paddy rice is overwhelmingly greater than that of other crops. In short, more than about 90% of the arable land is occupied by paddy fields. The yield per hectare is 1.14 tons or approximately 80% of the average of 1.44 tons for whole Thailand in the same year (1962).

Paddy rice cultivation is commenced as soon as the rainy season sets in. Transplanting method is general practice in this area. The seedling bed is made in the middle of May and 45 - 60-day-seedling is transplanted into the field. In a part of the inundation area along the river, broadcasting method is performed. Harvesting is started in November when the rainy season has ended.

Agricultural work appears to be depended on exclusively manual and animal power. In regard to fertilizers, there are some farmers seen to use small amounts of ammonia, but there are almost no agricultural chemicals used for paddy rice.

Table A-2-2 Area of Land Holding by Size by Amphur Muang, Ban Na and Pak Phlı

	Muang		Ban Na		Pak Phli		Total	
	Area (rai)	%	Area (rai)	%	Area (rai)	%	Area (rai)	%
Under 2	152	0.1	63		21		236	0.1
2 - 3.9	858	0.4	587	0.4	147	0.2	1,592	0.4
4 - 5.9	1,166	0.6	823	0.5	274	0.3	2,263	0.5
6 - 7.9	1.090	0.5	699	0.4	362	0.4	2,151	0.5
8 - 9.9	1,363	0.7	914	0.6	431	0.4	2,708	0.6
10 - 14.9	5,376	2.7	3,827	2.4	1,718	1.8	10,921	2.4
15 - 19.9	7,439	3.7	5,454	3.4	2,304	2.4	15,197	3.3
20 - 24.9	11,555	5.8	9,939	6.3	5,274	5.5	26,768	5.9
25 - 29.9	11,824	5.9	12,525	7.9	5,135	5.4	29,484	6.5
30 - 34.9	17,885	9.0	15,660	9.9	7,486	7.8	41,031	9.0
35 - 39.9	13,617	6.8	12,083	7.6	6,849	7.1	32,549	7.2
40 - 44.9	18,010	9.0	16,175	10.2	8,874	9.3	43,059	9.5
45 - 49.9	11,570	5.8	10,136	6.4	7,104	7.4	28,810	6.4
50 - 54.9	15,407	7.7	12,952	8.2	8,560	8.9	36,919	8.1
55 - 59.9	7,756	3.9	7,895	5.0	5,304	5.5	20,955	4.6
60 - 99.9	45,051	22.6	30,465	19.3	24,715	25.8	100,231	22.1
100 - 139.9	16,226	8.1	10,597	6.7	8,298	8.7	35,121	7.7
140 - Over	13,258	6.6	7,342	4.6	2,962	3.1	23,562	5.2
Total	199,603	100.0	158,136	100.0	95,818	100.0	453,557	100.0

Source : Cencus of Agriculture 1963 (Changwat Nakhon Nayok)

Table A-2-3 Number of Land Holdıng by Amphur Muang, Ban Na and Pak Phli

	Total Holdıng	Owner	Cash renter	Crop renter	Other
Changwat Total	17,219	11,490	410	2,953	2,366
Amphur Muang	6,064	4,164	157	1,184	559
Amphur Ban Na	4,743	3,122	115	900	606
Amphur Pak Phlı	2,455	2,043	1	128	283

Source : Cencus of Agricilture 1963 (Changwat Nakhon Nayok)

Table A-2-4 Holding, Areas and Production of Main Crops in Changwat Nakhon Noyok

Crops	Total Holdings	reporting Holdings	Planted Area		Harvested Area		Number of trees	Number of bearing trees	Average Yield (kg)				Ave. per holding Reporting		Ave. No. of Trees per holding Reporting
									Planled Area		Harvested Area				
			ral	ha	ral	ha			ral	ha	ral	ha	ral	ha	
Rice	16,626	15,193	628,248		580,561				168.2		182.0	1,140			
Fresh Chilli	17,219	19	27										1.4		
Water Melon	17,219	42	274										6.5		
Stem Vegetables	17,219	117	152										1.3		
Root Crop	17,219	381	1,039										2.7		
Fruit Bearing Vegetable	17,219	436	589										1.4		
Coconut	17,219	7,533					62,870	9,241			(227,805)				8
Durian	17,219	417					3,783	1,048							9
Mango	17,219	10,005					148,529	94,394							15
Sugerpalm	17,219	2,817					15,132	2,638							5
Ranbutan	17,219	876					8,573	3,422							10
Orange	17,219	3,445					29,592	13,198							9
Lime	17,219	3,717					15,943								4
Tamarind	17,219	5,914					17,637								3
Jack fruit	17,219	4,403					25,852								6
Betal-nut	17,219	2,539					19,780								8
Kapok	17,219	5,448					30,965								6
Jute	17,219	327													
Ground nut 1/	17,219	178			137						135 kg				
Cassava	17,219	180			1,150						2				
Sugar-Cane	17,219	232			218						3				
Pine apple 2/	17,219	976			861						278				
Banana	17,219	2,116			2,511						624				

1/ Yield per ral in number instead of kg.

2/ Yield per ral in bunch instead of kg.

Source : Census of Agriculture 1963 (Changwat Nakhon Nayok)

A-2-3 Plan of Irrigation

(1) Selection of Irrigable Area

As for the downstream area, which would be effected by the Khlong Tha Dan Project, two areas below could be considered.

i) The existing Nakhon Nayok Irrigation Project spreaded out on the southern side of Highway No. 33.

ii) The area spreaded out on the northern parts of Highway No. 33.

With respect to i), since irrigation facilities are already provided and there is almost no necessity for construction of these facilities, the paddy rice (2nd crop) and upland crops would be introduced even in the dry season in addition to the crops in the rainy season. The benefit expected in second crops is regarded as the main benefit of this project.

Regarding ii), since there are no irrigation facilities available at present, intake facilities, waterways, distribution channels and terminal works will have to be constructed. At relatively high elevations of 20 m - 40 m, upland crops (especially fruit trees and other perennial crops) could be newly introduced and high benefits would be expected.

The selection of either i) or ii) should be determined according to the result of further investigation. Especially, it would be necessary to have a grasp of the conditions of farm management, irrigation water requirements for farm management, and variations in water requirements in the future of the existing Nakhon Nayok Irrigation Project.

Information about these problems was not available in the present survey, so that it was assumed tentatively in this study that area of ii) would be developed. Further, it was decided in this plan that only dry season irrigation would be the objective, because runoff in the rainy season would be almost assigned to the existing irrigation project.

After clarification of water utilization, including existing water right on the downstream in the rainy season, surplus water, if any, would be utilized for the irrigation of the Khlong Tha Dan Project.

(2) Plan of Development

According to the 4-year and 9-month observation records obtained at Ban Khlong Si Sook Gaging Station, the driest year was 1968. The monthly average discharges in that year after Completion of the Khlong, Pun and Tha Dan Power Stations are shown in the table below. These would be the minimum discharges which can be utilized for irrigation in the dry season.

Available Discharge for Downstream Irrigation Area

(Unit : Cu.m/sec)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Available Discharge for Irrigation	12.0	10.8	8.9	8.0	13.8	15.5	33.0	40.2	30.0	18.0	15.9	12.2

The state of land utilization was estimated from 1/50,000-scale topographical maps and Census of Agriculture, Changwat Nakhon Nayok (1963). The proposed area was taken to be the area surrounded by the four lines shown below on the both banks of the Nakhon Nayok River.

Upper Limit (Northern Limit) : EL. 40 m line

Lower Limit (Southern Limit) : Highway No. 33

Western Limit : Huai Nang Ri River (border between Amphur Ban Na and Amphur Muang)

Eastern Limit : Khlong Yang River

The state of land utilization is shown in Table A-2-5.

Table A-2-5 Available Area by Land Category (ha.)

	Present	Plan		Remarks.
		1st crop	2nd crop	
Paddy Field	10,600	10,600	4,000	
Orchard	650	1,750	1,750	
Upland	650	650	650	
Pasture land	1,100	—	—	
Total	13,000	13,000	6,400	

The irrigation requirements for the second crop in the dry season were obtained as shown in Table A-2-6 referring to the report 1/ on the adjacent Nam Sai Yai Project. The irrigable area in the dry season was decided to be 6,400 ha.

Table A-2-6 Water Requirement for Proposed Irrigable Area (6,400 ha)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Remarks
Paddy Rice (2nd Crop)	0.24	2.96	7.04	6.00	5.68	0.48	4,000 ha
Upland Crops	1.82	1.18	1.85	1.87	2.16	0.65	2,400 ha
Total	2.06	4.14	8.89	7.87	7.84	1.13	

Further, if all of streamflow in the dry season were to be used for upland crops, the irrigable area would be approximately 10,000 ha.

(3) Irrigation Works

The water requirement for the irrigable area of 6,400 ha in the dry season (second crop) is shown in Table A-2-6, which will be conveyed from both banks of the Nakhon Nayok River. The proposed irrigation area by district are shown in Table A-2-7.

Table A-2-7 Proposed Irrigable Area by District

	Irrigable Area (ha)		
	Left Bank of Nakhon Nayok River	Right Bank of Nakhon Nayok River	Total
Paddy Rice (2nd Crop)	2,000	2,000	4,000
Orchard	750	1,000	1,750
Upland Crops	350	300	650
Total	3,100	3,300	6,400

1/ Feasibility Report, Nam Sai Yai No. 2 and No. 3 Hydroelectric power (1968)

The maximum capacity of the waterways and the length would be 5.4 cu.m/sec and 16 km long respectively on the left bank, and 5.3 cu.m/sec, and 26 km long on the right bank (see Fig. A-2-1).

(4) Cost of Irrigation Works and Economic Evaluation

The cost of irrigation works, annual cost and annual benefit were determined referring to the beforementioned Nam Sai Yai Project Report. In other words, the cost of irrigation works including intake facility waterways, land reclamation, terminal works, etc., was assumed to be ฿10,700 per ha, the annual cost ฿1,000 per ha, and the annual benefit ฿2,500 per ha. As a result, the surplus benefit, and the ratio of benefit and cost due to the irrigation project would be ฿1,500 per ha and 2.5 respectively. Therefore, it may be said the agricultural aspect of the Khlong Tha Dan Project would be promising.

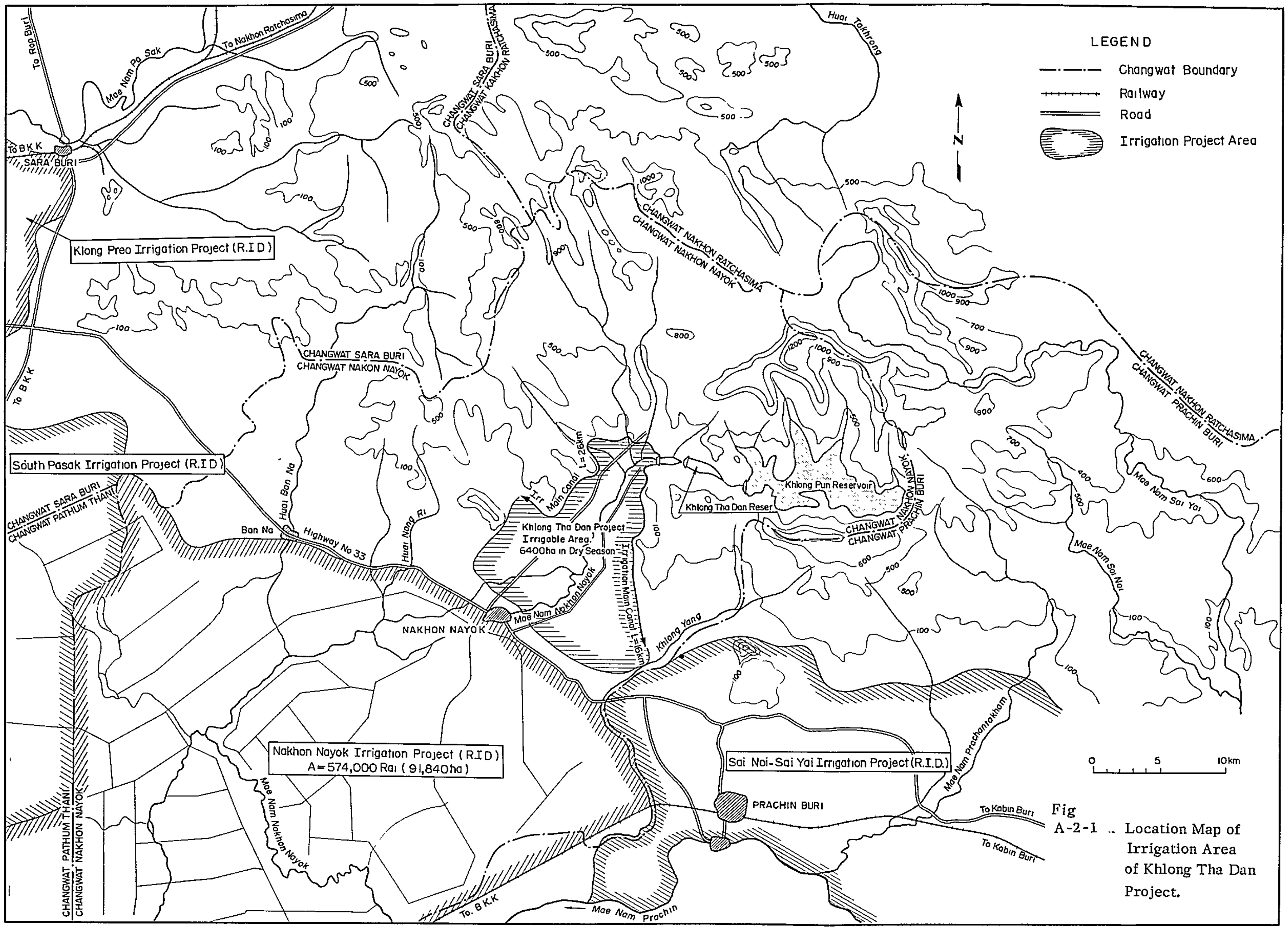

Fig A-2-1 .. Location Map of Irrigation Area of Khlong Tha Dan Project.

A – 3

LIST OF BASIC DATA

I. Topographical Map

Scale of 1 : 250,000	2 sheets	Sheet No. ND 47-8, 12
Scale of 1 : 50,000	9 sheets	Sheet No. 5254 (I - IV) Sheet No. 5253 (I - IV) Sheet No. 5253 (IV)
Scale of 1 : 10,000	4 sheets	Project Area (No. 1 - No. 4)

II. Aerial Photography

Scale of 1 : 40,000	24 sheets	Project Area

III. Highway Map

Scale of 1 : 1,000,000	1 sheet	Northern Region
Scale of 1 : 1,000,000	1 sheet	Central Region
Scale of 1 : 1,000,000	1 sheet	Southern Region
Scale of 1 : 1,000,000	1 sheet	North-Eastern Region

IV. Hydrological Data

(a) Daily precipitation

Ban Khlong Si Sook	5 yrs.	1966 (Jan.) - 1970 (Dec.)
Wang Heo	6 yrs.	1965 (Jan.) - 1970 (Dec.)
Ban Sapanhin	8 yrs.	1963 (Jul.) - 1970 (Dec.)
Kabin Buri	3 yrs.	1968 (Jan.) - 1970 (Dec.)
Prachin Buri	3 yrs.	1968 (Jan.) - 1970 (Dec.)
Nakhon Nayok	3 yrs.	1968 (Jan.) - 1970 (Dec.)
Saraburi	3 yrs.	1968 (Jan.) - 1970 (Dec.)
Si Khin	3 yrs.	1968 (Jan.) - 1970 (Dec.)

(b) Daily discharge

Ban Khlong Si Sook	5 yrs.	1965 (Apr.) - 1969 (Dec.)
Wang Heo	6 yrs.	1965 (Jan.) - 1970 (Dec.)
Ban Sapanhin	6 yrs.	1965 (Jan.) - 1970 (Dec.)

(c) Yearbook

1965 Hydrologic Data	1	
1965 Hydrologic Data	2	Volume I, II
1967 Hydrologic Data	1	Volume II

(d) Daily Max. and Min. Temperature

Ban Khlong Si Sook	2 yrs.	1968, 1970

(e) Daily evaporation

Ban Khlong Si Sook	3 yrs.	1968 - 1970

(f) Location maps

Location of hydrologic stations	1 sheet	1970. NEA
Location of stream gaging stations	1 sheet	1965. RID
Location of hydrologic observation stations	1 sheet	1968. RID

V. Geological Data

Geological Map of Thailand and Geology of Thailand	2 sheets

VI. Electrical Data

Thailand Electric Power Load Forecast	1
Electric Power in Thailand 1969	1
Electric Power Statistics for Thailand (1969)	1
Hydro Electric Power Potential in Thailand	1
Projections of Sectional Outputs and Employment	1
Electric Rate Schedule	3 sheets

VII. Agricultural Data and Others

Agricultural Statistics of Thailand (1967)	1
Census of Agriculture (1963) Changwat Nakhon Nayok	1
Changwat Saraburi	1
Types of Forests, National Parks and Wild Life Preserved Areas	1

A – 4

HYDROLOGICAL DATA

A-4 Hydrological Data

(A) Data of Precipitation

(1)	Ban Khlong Si Sook	from May 1965 to Dec. 1970
(2)	Nakhon Nayok	from Jan. 1952 to Dec. 1970

(B) Data of Daily Discharge

(1)	Ban Khlong Si Sook	from Apr. 1965 to Dec. 1969

(C) Data of Daily Evaporation

(1)	Ban Khlong Si Sook	from May 1965 to Dec. 1970

A-4 (A)

(1) Monthly Precipitation STATION BAN KHLONG SI SOOK CATCHMENT AREA 196 sq km

KHLONG THA DAN RIVER IN THE BASIN OF ELEVATION m UNIT mm S ° W °

YEAR	Jan.	Feb.	Mar	Apr.	May	June	July	Aug	Sept.	Oct.	Nov	Dec.	ANNUAL Total
1965					403.8	788.4	368.1	830.9	509.8	162.9	162.1	1.6	3,227.6
66	0.0	39.3	20 0	34.8	593.4	556 0	1,082.5	1,028.4	443.5	194.3	11.0	18.1	4,021.3
67	2.3	0.0	0.2	129 3	343.4	286.0	643.3	761.6	441 3	210.8	47.0	0.0	2,865 2
68	1.6	195.2	17.6	177.7	224.5	395.0	691.5	612.1	378.9	139.2	31.1	1.6	2,866.0
69	26.0	18.6	95.6	21.9	141.3	718 8	1,088.5	430.7	525.8	171.6	11.1	0.0	3,249 9
70	0.0	111.8	66.0	164 8	346.6	600.2	450.2	554.5	459.0	185.6	10.1	13.7	2,962 5
Total	29.9	364.9	199.4	528.5	2,053.0	3,344.4	4,324.1	4,218.2	2,758.3	1,064.4	272.4	35.0	19,192 5
Mean	6.0	73.0	39.9	105.7	342.2	557.4	720.7	703.0	459 7	177.4	45.4	5.8	3,236.2

Daily Precipitation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ______ ELEVATION ______ UNIT mm YEAR 1965

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1						22 8		0.5	0.2	24 7	41.5		1
2						82.9		27.9	1.1	0.2	1.7		2
3					32.5	11.6		16 8	3 3	0.2	39.5		3
4					0.6	15.8		84.0	25.1	2 4	0.9		4
5					2.2	7.6	32.6	71.4	4.4	7.9	17.0		5
6					1.9		10 5	73.8	47.3	6.8			6
7					11.7	0 8	10.5	79 0	9.6	2.6	0.4		7
8						0 7	12 5	21.2	1.7	24 1			8
9					1.8	40.3	7 7	25.4	12.7	3.4			9
10					0.3	31.0		0.2	80.0	0.2			10
11					13 5	38.0		0 4	1.1	1.9			11
12						2.1	30.5	0.5	17.3	24.9			12
13						4 3	14.8	0 3	11.1	3.7		1.6	13
14						9.5	2 5	29.3	9.5				14
15					22.9	10.5		0.3	56.4				15
16					0.5	5 5		9.3		0.4			16
17					17.3	36 7	74.6	41.6	1.3		32.2		17
18					23.5	33.5	2.7	1.0			2.1		18
19						76.5	1.6	5.8	36.0		1.7		19
20					10.0	21.5	15.7	7.6	31.0		25.1		20
21						137.0		47.3	10.7				21
22					3 1	23 0	7.7	17.1	21 6				22
23					55.8	27.0	44.6	10.1	0 7	2.4			23
24					37.5	62.7	20.3	9.9	2.7	12 8			24
25						6.2	6.1	4.0	36.4	8.9			25
26					5 3	22 3	1 3	8.0	1.2	5 8			26
27					30.0	31 4	4.3	7.8	37 4	5.2			27
28					42.3	11.1	24.8	11.7	18 5	0 8			28
29					32.1	5.6	4.4	150.7	25 7				29
30					22.2	10.5	26.4	31.5	5.8	19.5			30
31					36.8		12.0	36.5		4.1			31
Total					403.8	788 4	368.1	830.9	509.8	162.9	162.1	1.6	

Annual Total ( )

Daily Precipitation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ______ ELEVATION ______ UNIT mm YEAR 1966

DATE	Jan	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	DATE
1			10.2	11.6			81.5		0.9				1
2		3.1					137 2	3.2	1 3				2
3						1 6	33 5	98 4	7.9				3
4					37 8	33.0	17.5	15.2	0.7				4
5					36 0	6.1	18 0	2.7	32.7	15 8			5
6					9 2	10 1		19.9	28 6	29.3			6
7					22 1			11.5	57 9	3.6			7
8					54.5	15.0	3 8	3.7	11.4	14.9			8
9					34.3	2.6	4.1	91.6	12.7	34.2			9
10					115 4	1.8	6 0	61 5	9 6	5 8			10
11						0.8		39.3	13.1	17 7			11
12								7.3	7.8	17 6			12
13						13.5	50.2	76 3	33 4	2.9			13
14				1.0		52.2	48.0	60 0	56.1	0.9	11.0	4 7	14
15					1.5		87.2	9 3	1 9	0.7		1.6	15
16			0 9		25 9		9.7	61 5	54.6	0.8		5.6	16
17			0.7		17 1	47 8	25.7	44 3	21.6	8.6			17
18					11 1	19.3	24.6	0.8	43.5	1.9			18
19				3 8	2.7	76.5	39 4	0 8	20 3				19
20		16.5		17 2	1.6	31 8	178.8	2.2	1 3				20
21					5.5		52.1	2.9				4.7	21
22					12.9	59 0	50 0	65 0				1.5	22
23		17.4			22.0	1 8		24.0					23
24				1.2	3.7		125.1	25.0	9.3	36.0			24
25		2.0			35.6	2 5	7.0	7.2					25
26					24.7	0.6	50.6	147.5					26
27		0.3			30.7	123 1	12 0	32.6					27
28					8.4	41.4	20.5	7.5		5.6			28
29					57.3	3 5		68.7	9.9				29
30					19.1	12.0		14.1	7.0				30
31			8.2		4.3			24.4					31
Total	0.0	39.3	20.0	34.8	593.4	556.0	1,028.4	1,082.5	443.5	194 3	11.0	18.1	

Annual Total ( ) 4,021.3

Daily Precipitation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1967

DATE	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1						0.8	20.8	42.2	0.5	18.0			1
2						1.5	3 4	40.8	11.1	51.6			2
3						0 9	0.2	42.3	14.3				3
4						14.0	31.3	18.9					4
5						0.6	48.0	7.3	15 0				5
6			0.2			0 5	61.3	30.2		10.0			6
7				2.5			40.6	5.2	85.5				7
8					6.3	0.5	46 3	20.2					8
9						5.3	16.8	79.2	41 5	0.5			9
10					30.0	8.6	6.0	4.6	12.5	6.4			10
11					2.0	65.1	8 2	71.1		9.9	7.9		11
12					2.0	15.1	9.7	2 5	3.5	100.7	24.3		12
13				31.0	6.6	4.4	65.7	23.6	27.9	0 5	4 1		13
14					17.6		14.8	12.7	14.5				14
15				0.5	21.7		2.1	33.5	12 0				15
16				1.4	5.2		14.9	19.4		7.0			16
17				24 0	6.2	57.5	25.3	7.0	6 6				17
18					7.4	27.3	21.3	3 1	20.0				18
19					58.0	1.0		177.4	1.4				19
20					4.9		43.5	15.8	27.9				20
21				0.5			56 0	43.1	0 5				21
22				11 0	55.5				19.0				22
23				9.6	9.7	2.7	1.0	1 5	35.0				23
24				12.0	13.1		29 0		3.2	5.7			24
25				29.0	33.9		35.1		29.5	0.5			25
26					15.9	22.0	33 0	4 6	50.3				26
27				4.4	37.8	2.1	0.2	32.9	7.5				27
28				3.4	1 8	0.6		6.5	0.9		8.5		28
29					7.3	11 6	2.6	10.0	1.2		2.2		29
30					0.5	43 9	0.5	5 3					30
31	2.3						5.7	0.7					31
Total	2.3	0.0	0.2	129.3	343.4	286.0	643.3	761.6	441.3	210.8	47.0	0.0	

Annual Total ( )	2,865.2

Daily Precipitation STATION

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1968

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1					12.4	3.2	11 9	70 4	8.2	4.3	0 8		1
2					2.5	22 4	3 9	63.7	19.2	1 3			2
3					3.0	19.8	52.2	22 4					3
4					55 6	2.7	29.7	20 1	52 9	24 8			4
5				12.1	20.1		8 4	9.9	10 2	7.9			5
6				3.1	37 0			26.5	7.2		2 8		6
7					17 5			14 4		4.3			7
8					7 7	18.4	60 0	42 0			1.9		8
9		16 6			11.5	5 8	25 8	55 4		37.2	6.2		9
10					0.5			16 6	12 4	8 0			10
11						2.9	28.7	2.4	35.4	5.2			11
12			7.2			7 2		18.9	82 1		1.7		12
13			6.4			7 8		12 8	18 6	11.2	15 5	1.6	13
14				22 1			27.8	23 4	8 8				14
15							46 2	24.4	1.5	1.2			15
16						70 5	1.5		2.4	31.5			16
17			4.0			13 1	9.3	19 4	3 3	1 2			17
18				5.6	5.1				4.6				18
19		61 2		25 1		26.5		40.7	8 1		2 2		19
20		41.6				0 9		6.9	3 7				20
21				0 5			44.3	32.7	0.9				21
22							71 4	19 5	25.5	1.1			22
23		61.4		8.4		5.8	29.8	6.7	8.9				23
24		7 4		3.3		27.5	80.7	9 1	7 7				24
25				23 2			3 8		26 6				25
26	1.6	7 0				1.3	12.2	4.5	18 6				26
27						71.2		17.2	0 6				27
28				3 2		8 4	3 7						28
29				5 7	40 5	4 2	110 4	29.7	11.5				29
30				65.4	8 0	75.4	7 1						30
31					3.1		22.7	2.4					31
Total	1.6	195 2	17.6	177.7	224.5	395 0	691.5	612.1	378 9	139.2	31.1	1 6	

Annual Total ( )	2,866.0

Daily Precipitation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1969

DATE	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	DATE
1					1 6	14 8	71 7	27.1	12 2	7.3	4 5		1
2		18.6			24 3		19 7	1.7	52.4	6 2	2.5		2
3						18 1	26 5	21 0	19 7	5 4	4.1		3
4				8.9				30.2	71 3				4
5						40 6	87.7	25 6	38 6				5
6	14.0				6.5	68 0	47 7	36 0	5 1				6
7					1 3	67 0	10 6	34.1	4 0				7
8					8 2	20.6	45 0	10 8	6 3				8
9						19.9	25 5	2 1					9
10				5 4		49 4	8.7	22 7	0 6				10
11				0 1		59 7	6.9	27 7	7 0	0.7			11
12				0 3		12 9	103.3	10 9	4 6	22.6			12
13			4 8	0 3		53 4	42 0		25 2	8 1			13
14			22.2				5 9	7.6	1 4				14
15			16 2				9 0		38 4	13 2			15
16							40.0		7.7	8 8			16
17			11 3			2.2	53 2	3.1	0.5	9 5			17
18						13.2	63 8		55.5	3.4			18
19	1.4				14.5	50.0	23 2	3.7	14.4				19
20						34 8	0.5	51 2	56 0				20
21					0 3		3.4	10.5	10 0	1 3			21
22			33 6		0 3			6 0		30 6			22
23			6 3		21.0		265.8			24 3			23
24	8.4		1.2		3 2	20 6			20 3	9.2			24
25					4 2	4 6							25
26						1.0	14 3		4 3	1.6			26
27				6 2	6.1	13.1	35 6		46 6				27
28				0 1	13 4	64.2	54.2	36.2	6 7	0 8			28
29	2 2				4.7	46 8	8 0	4 8	6 6	5.7			29
30				0.6	18.3	43 9	10 6	47 9	10 4	1.5			30
31					13 4		5 7	7 8		11.4			31
Total	26 0	18 6	95 6	21.9	141.3	718 8	1,088.5	430 7	525 8	171 6	11.1	0 0	

Annual Total ( ) 3,249 9

Daily Precipitation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1970

DATE	Jan	Feb	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov	Dec.	DATE
1			6 9	21 4				94.4	42 1			2 3	1
2				15.5	0 8	3 1	2 4	31.6	1.3			6 3	2
3					3.9	21.8	5 1	24.9	36 4				3
4						5 3	20 2	6 3	3 0			0 7	4
5			10 4			4.2	19.5		43 2				5
6						22 1	0 8	11 4	48 0				6
7						57.0	22 2	21.7	22 3	2 6			7
8				21.1		37.0	55.4		6 0	13.8			8
9		94.5				1 4	27 4		0 4	1 0			9
10							29.2		10.9				10
11		6.4			45 2		26 2		66 1	8 8			11
12		0 2		56 0	64.4	31 5	29 0	3 1	21 3	9 2			12
13					62.4	27.2	6 7	34.5		43 9		4.4	13
14						26.4	5 0	49.4		5.0	6 7		14
15					20 2		12.7	34.7	3 4	2.8			15
16						18 9	4.9	4.7	57.0	43 6			16
17		10 7			20 1	88.4	13.8	12.7	17 6	1.3			17
18					24.1	15 8	7.7	29 9	5 0	18.6			18
19					4.7	30 2		13 3	8 7				19
20					11 6	20.8		8 8	1 5				20
21				0 8		24.1		17.3	8 0				21
22			18 7	4 4		19.2	51.7	25 0		12 9			22
23			28 5		34 8	36 2	13 0	1 8	0 8	3 0			23
24				15 8		6 4	1 5	24 0					24
25						3.6	4 5	28 2		5.7			25
26				14.3	40 2	15 6	36.2	44.4	21.2	6 9			26
27			0.5			12.2		13 0		3 6			27
28				10.5		9.6	2.2	2 0	28 8				28
29					14 2	63 2	48.7		6 0	2 9	1 4		29
30				5 0				17.4			2.0		30
31			1.0				4.2						31
Total	0.0	111.8	66 0	164.8	346 6	600.2	450.2	554.5	459 0	185.6	10 1	13.7	

Annual Total ( ) 2,962.5

(2) Monthly Precipitation

STATION NAKHON NAYOK CATCHMENT AREA sq·km

RIVER, IN THE BASIN OF ELEVATION m UNIT mm S ° W °

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	ANNUAL Total
1952	0.0	26.9	138.7	43.2	229.2	329.4	374.0	420.2	443.9	264.8	28.7	0.0	2,299.0
1953	29.7	79.4	114.2	67.1	273.6	297.9	370.0	296.6	337.0	145.9	80.5	7.4	2,099.3
1954	60.3	2.5	109.7	169.0	249.0	416.4	364.7	899.7	577.1	81.1	0.0	0.6	2,930.1
1955	0.0	31.1	50.8	140.9	377.1	495.0	282.2	231.7	356.8	172.5	78.6	0.0	2,216.7
1956	23.7	0.0	97.0	178.0	296.6	371.0	540.6	431.3	669.3	242.7	42.0	0.0	2,892.2
1957	5.3	3.6	32.2	98.3	159.9	307.4	318.5	658.2	660.4	527.8	52.6	0.0	2,824.2
1958	0.0	109.3	4.0	109.3	54.6	379.2	282.4	243.9	446.4	180.0	0.0	0.0	1,809.1
1959	0.0	24.9	49.4	196.6	127.1	136.4	397.9	284.7	441.3	238.0	18.4	7.8	1,922.5
1960	0.0	0.0	57.6	18.6	144.0	442.4	323.1	314.0	434.6	306.0	94.1	0.0	2,134.4
1961	0.0	21.4	59.3	119.9	358.1	315.6	246.0	681.2	450.7	322.2	26.5	0.9	2,601.8
1962	0.0	8.9	0.0	142.4	286.1	480.4	424.1	239.0	409.8	201.9	1.3	0.0	2,193.9
1963	0.0	22.4	35.9	44.4	77.9	178.0	319.8	485.4	385.7	214.7	42.8	1.9	1,808.9
1964	0.0	4.0	3.2	38.2	273.2	106.2	210.5	207.4	195.3	239.3	0.1	0.0	1,277.4
1965	0.0	15.1	8.4	0.5	272.9	251.9	171.4	126.3	211.6	66.9	27.9	0.0	1,152.9
1966	0.0	0.2	0.3	15.2	404.4	207.6	313.0	601.2	315.7	192.7	7.3	62.1	2,119.7
1967	0.0	0.0	0.0	22.9	138.4	184.6	383.1	327.6	341.3	216.6	76.8	0.0	1,691.3
1968	0.9	59.8	20.5	94.1	152.9	53.4	325.8	407.8	255.6	69.9	42.0	0.0	1,482.7
1969	0.6	0.0	61.2	91.9	173.5	371.5	297.4	122.0	523.8	125.0	4.8	0.8	1,772.5
1970	0.0	19.4	9.6	31.0	154.9	189.6	154.7	173.3	140.1	43.1	1.4	1.7	918.8
Total	120.5	428.9	852.0	1,621.5	4,203.4	5,513.9	6,099.2	7,151.5	7,596.4	3,851.1	625.8	83.2	38,147.4
Mena	6.34	22.57	44.84	85.34	221.23	290.21	321.01	376.39	399.81	202.69	32.94	4.38	2,007.75

A - 4 (B)

Monthly Mean Discharge STATION BAN KHLONG SI SOOK CATCHMENT AREA 196 sq·km

Khlong Tha Dan RIVER, IN THE BASIN OF ______ ELEVATION ______ m UNIT m3/S S ° W °

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	ANNUAL
1965	-	-		2.95	16.2	39.2	20.0	47.5	25.2	8.72	3.08	0.60	-
1966	0.17	0.10	0.07	0.04	5.72	20.2	56.6	49.6	27.3	7.70	1.78	0.51	14.14
1967	0.12	0.05	0.00	0.08	2.42	8.79	31.4	42.9	21.0	10.6	1.38	0.32	9.92
1968	0.08	0.11	0.05	0.13	3.58	6.89	27.2	29.9	26.1	8.31	1.02	0.21	8.63
1969	0.06	0.02	0.01	0.00	0.12	18.60	76.9	30.6	38.4	9.63	3.41	0.78	14.88
Total	0.43	0.28	0.13	3.20	28.04	93.68	212.1	200.5	138.0	44.96	10.67	2.42	
Mean	0.11	0.07	0.03	0.64	5.61	18.73	42.42	40.10	27.60	8.99	2.14	0.48	12.24

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Daily Discharge STATION BAN KHLONG SI SOOK

Khlong Tha Dan RIVER, IN THE BASIN OF ______ ELEVATION ______ UNIT m3/S YEAR 1965

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1				3 31	2.31	13.2	16 2	26.2	42.1	33.6	6.81	0.88	1
2				3.66	1.95	19.7	12.7	28.4	25 6	23 6	8 44	0 88	2
3				3.83	3.31	8.06	9.96	44.0	19.2	19.2	5.84	0.83	3
4				4 00	3.02	5 59	8 06	115	21.5	18.7	7.06	0.88	4
5				3.83	3 66	21.5	11.1	94.3	18.2	18.7	7 06	0.83	5
6				3.48	3.31	10.3	10.7	120	30 6	15.2	6 32	0 83	6
7				4.34	3.02	8 82	10.7	115	22.9	15.7	4.69	0.78	7
8				4 69	3.02	8 82	17.2	193	17 2	15.2	4.00	0.78	8
9				4.00	3.66	40.4	10 7	63.4	13 6	11.1	3 48	0.72	9
10				3 66	3.83	64 6	8.44	33.6	18 7	9.20	3.14	0.67	10
11				3.48	5.84	50.0	7 06	22.2	13.6	8.44	2.78	0 67	11
12				3.14	6.57	37.8	6.57	15.7	14 8	9.96	2.54	0.61	12
13				3.02	6.08	37.0	11.1	12.7	12.7	7.06	2.43	0.61	13
14				3 14	7.68	35 3	8.06	10 7	26.2	6.08	2 19	0 56	14
15				3 02	7 06	26.9	6 81	11.9	40 4	5 35	2.19	0.56	15
16				2.90	6.57	40.4	6.32	12 3	20 2	4 86	2 07	0.56	16
17				2.66	7.06	44 0	32.2	14.4	14.8	4.34	2 31	0.53	17
18				2.54	15.7	52 0	15.7	11.5	11.9	3.83	2.19	0 51	18
19				2.43	11.5	63.4	11.9	10.7	22 2	3.48	2.19	0.51	19
20				2.43	11.1	62 3	12.3	41 3	31.4	3.14	2.43	0.51	20
21				2.31	8 06	107	9.20	30.6	22.9	2.90	1 70	0 48	21
22				2 31	7 30	44 0	7 68	35.3	38.7	2.66	1.52	0 48	22
23				2.19	11.5	32.2	22.2	18.7	24 2	2.66	1.44	0.46	23
24				2.19	21.5	104	39.6	28.4	29 9	2.54	1.36	0.46	24
25				2 19	22 9	46 0	32.2	20.9	30.6	2.66	1.27	0.46	25
26				2.07	18.2	51.0	32 9	17.7	20.2	2.54	1.18	0.46	26
27				1.95	37.8	49 0	34.4	18.2	32 2	2.31	1.10	0.43	27
28				1.95	63.4	31.4	117	22.9	31.4	2.19	0 99	0.43	28
29				1.86	74.4	38.7	32 9	115	54.2	2.54	0.94	0 40	29
30				1 86	53 0	23.6	29.9	76.9	35.3	6.81	0.88	0.40	30
31					68.3		27 6	92.9		3.83		0.38	31
Total				88.44	502 61	1,176.99	619 36	1,473.8	757.4	270.38	92.54	18.55	
Mean				2.95	16.2	39.2	20.0	47.5	25.2	8.72	3.08	0.60	

Annual Total ( )

Daily Discharge STATION BAN KHLONG SI SOOK

Khlong Tha Dan RIVER, IN THE BASIN OF ______ ELEVATION ______ UNIT m3/sec YEAR 1966

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	0 28	0.11	0 11	0 01	0.01	13 4	13.8	17 5	32.0	5.74	4.28	0.73	1
2	0.25	0 11	0.20	0 02	0 01	8 56	97.7	14.7	22.7	4.70	3 88	0.73	2
3	0 25	0.13	0.18	0 07	0 01	6.37	90 8	12.2	17.0	4.28	3.46	0 69	3
4	0 25	0.13	0.16	0 07	0.01	4.70	49 0	29.3	13 8	3.67	3 26	0.65	4
5	0.22	0.11	0.13	0.11	0.07	4.08	37 7	25.3	15.2	3.46	2.85	0 57	5
6	0 22	0.09	0.13	0 07	0.35	3.06	37.0	17.5	20 8	4.49	2.73	0.57	6
7	0 20	0.09	0.11	0.06	0.28	3.46	21.4	51.6	16.6	12.2	2.38	0 53	7
8	0 20	0 09	0.11	0.04	0.38	2.50	14.3	30.6	25.3	8.04	2.38	0.53	8
9	0 20	0 09	0.11	0 04	0.85	4.70	11.9	22.7	97 7	11.6	2.15	0.53	9
10	0.18	0 09	0.09	0 02	3.06	4 70	10.6	49.9	45.6	11.6	2.15	0.49	10
11	0 18	0.07	0.07	0 02	2.62	5.11	8.30	57.0	33.4	10.6	2.03	0.45	11
12	0 18	0 07	0 07	0 02	1.02	4.49	7.78	56 1	24 0	10.3	1.91	0.45	12
13	0.18	0.07	0 06	0 01	0.65	3 46	6.58	37.7	22.7	9.34	1.68	0.42	13
14	0 18	0.07	0.06	0 01	0 42	9.34	7.00	174	24 7	9.34	1.80	0.42	14
15	0.16	0.07	0.06	0.01	0.38	50 8	10 3	62.8	29.3	8.30	2.03	0.45	15
16	0 16	0.07	0.02	0 01	0.32	15.7	80 5	50.8	45 6	8.30	1.43	0.49	16
17	0 16	0 07	0 02	0.01	4 08	9.93	55 2	127	32.0	9.34	1.35	0.57	17
18	0.16	0.07	0.02	0.01	4.49	11 9	35 6	135	59 0	8.30	1.26	0.53	18
19	0.15	0 07	0.06	0 01	5.95	12.2	36.3	56.1	68 7	7 52	1.18	0 49	19
20	0.15	0 06	0.06	0 01	5 32	41.6	111	35.6	44 8	7 00	1.10	0 45	20
21	0.15	0.13	0.04	0 04	2.50	40.1	120	24.0	29.9	5 95	1.02	0 45	21
22	0.13	0.11	0.02	0 15	1.91	17.0	130	20.8	22.7	5.32	0.93	0.49	22
23	0.13	0.13	0.02	0.07	2.03	112	64 7	37.0	16 1	4.70	0 85	0.65	23
24	0.13	0.13	0.02	0.06	4.28	33.4	35 6	29.3	11 6	4.49	0 81	0.69	24
25	0 13	0 11	0.02	0 06	3 46	18.2	180	28.6	11.6	20 1	0.77	0 61	25
26	0.13	0.13	0.02	0.04	32.0	12.6	156	21.4	9.34	9.60	0.77	0.45	26
27	0 13	0 13	0.02	0 02	13.8	9.33	126	98.8	8 04	7.52	0 77	0 42	27
28	0 13	0.13	0.01	0 02	16.6	90.8	85 0	66 7	7 00	6.79	0.73	0.40	28
29	0.13		0.01	0 02	16 6	32.0	56.1	45.6	6.79	5.95	0.73	0 38	29
30	0.11		0.01	0 02	30 6	20.1	33.4	64.7	5 74	5 32	0 69	0 35	30
31	0.11		0.01		23.4		24.0	36.3	..	4.70		0.32	31
Total	5.32	2.73	2.07	1.13	177.46	605.59	1,753 56	1,536.6	819.71	238 56	53.36	15 95	
Mean	0 17	0.10	0.07	0 04	5 72	20.2	56.6	49.6	27.3	7.70	1.78	0.51	

Annual Total ( )

Daily Discharhe STATION BAN KHLONG SI SOOK

Klong Tha Dan RIVER, IN THE BASIN OF ________ ELEVATION ________ UNIT m^3/sec YEAR 1967

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	0.25	0.07	0.01	0.00	0.25	2.79	22.4	23.6	15.5	13.1	2.34	0.76	1
2	0.22	0.07	0.01	0.00	0.25	3.05	67.3	57.2	13.9	57.2	2.24	0.66	2
3	0.22	0.07	0.00	0.00	0.20	14.3	18.8	32.3	12.7	33.9	2.05	0.62	3
4	0.20	0.06	0.00	0.00	0.15	8.53	18.8	40.5	11.5	19.3	1.95	0.57	4
5	0.20	0.06	0.00	0.00	0.12	23.6	11.5	48.9	8.86	13.1	1.76	0.47	5
6	0.20	0.06	0.00	0.00	0.11	10.5	19.7	41.6	8.86	10.2	1.67	0.47	6
7	0.17	0.05	0.00	0.00	0.08	9.52	64.8	53.5	7.94	10.2	1.57	0.43	7
8	0.17	0.05	0.00	0.00	0.08	8.53	26.4	27.8	21.3	8.53	1.50	0.43	8
9	0.15	0.05	0.00	0.00	0.11	6.38	33.9	24.1	13.9	7.42	1.43	0.38	9
10	0.15	0.05	0.00	0.00	0.12	5.07	43.6	67.3	28.4	6.90	1.35	0.38	10
11	0.12	0.05	0.00	0.00	0.28	4.54	27.8	33.9	23.0	6.12	1.28	0.35	11
12	0.12	0.05	0.00	0.00	0.20	25.8	19.7	67.3	16.9	5.42	2.15	0.35	12
13	0.12	0.05	0.00	0.00	0.38	56.0	16.9	37.2	14.7	48.9	2.79	0.30	13
14	0.11	0.05	0.00	0.00	0.43	16.0	59.8	30.4	15.5	10.5	1.76	0.28	14
15	0.11	0.05	0.00	0.00	0.80	9.19	47.8	21.3	15.1	7.94	1.57	0.25	15
16	0.11	0.05	0.00	0.00	0.99	6.90	25.8	39.7	16.4	6.64	1.35	0.25	16
17	0.10	0.05	0.00	0.00	0.71	4.72	24.1	69.8	13.5	5.86	1.21	0.25	17
18	0.10	0.04	0.00	0.00	0.57	11.2	52.2	45.8	16.4	5.07	1.21	0.22	18
19	0.10	0.04	0.00	0.00	0.47	6.90	34.8	25.8	16.0	4.54	1.14	0.22	19
20	0.08	0.04	0.00	0.00	3.18	4.72	21.9	147.0	17.8	4.02	1.07	0.22	20
21	0.08	0.04	0.00	0.06	1.76	3.71	19.3	77.5	29.0	3.71	0.92	0.22	21
22	0.08	0.04	0.00	0.10	1.57	3.05	24.1	99.2	18.3	3.58	0.92	0.20	22
23	0.08	0.04	0.00	0.08	1.86	2.43	15.5	36.4	28.4	5.25	0.85	0.20	23
24	0.08	0.04	0.00	0.11	2.79	2.15	18.8	23.0	85.2	6.12	0.80	0.17	24
25	0.07	0.02	0.00	0.17	7.42	1.86	28.4	16.9	29.0	5.86	0.76	0.22	25
26	0.07	0.02	0.00	0.30	7.42	1.67	66.0	13.5	28.4	4.02	0.76	0.22	26
27	0.07	0.02	0.00	0.12	8.20	1.57	66.0	26.4	43.6	3.71	0.71	0.20	27
28	0.07	0.01	0.00	0.66	18.8	2.43	31.0	29.0	25.2	3.32	0.71	0.20	28
29	0.07		0.00	0.43	7.42	1.95	19.7	24.7	19.3	2.92	0.76	0.17	29
30	0.07		0.00	0.30	4.90	4.54	14.7	30.4	14.7	2.79	0.80	0.17	30
31	0.07		0.00		3.45		11.5	18.8		2.53		0.17	31
Total	3.81	1.29	0.02	2.33	75.07	263.60	973.0	1,330.80	629.26	328.67	41.38	10.00	
Mean	0.12	0.05	0.00	0.08	2.42	8.79	31.4	42.9	21.0	10.6	1.38	0.32	

Annual Total ( )

Daily Discharge STATION BAN KHLONG SI SOOK

Klong Tha Dan RIVER, IN THE BASIN OF ________ ELEVATION ________ UNIT m^3/sec YEAR 1968

DATE	Jan	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	0.14	0.05	0.07	0.02	2.31	1.62	33.6	20.7	16.1	12.1	1.81	0.42	1
2	0.14	0.05	0.07	0.02	1.90	3.61	41.8	52.5	18.3	11.4	1.81	0.38	2
3	0.10	0.05	0.06	0.01	0.91	6.29	20.7	46.2	14.4	10.0	1.81	0.38	3
4	0.10	0.05	0.06	0.01	1.24	6.94	39.9	33.0	12.1	9.43	1.62	0.38	4
5	0.10	0.04	0.06	0.01	23.2	6.50	53.4	23.8	37.4	18.8	1.62	0.38	5
6	0.09	0.04	0.05	0.01	12.1	4.48	30.6	18.8	24.9	13.5	1.43	0.34	6
7	0.09	0.04	0.05	0.02	13.5	3.12	19.3	21.7	25.4	12.1	1.24	0.34	7
8	0.09	0.04	0.05	0.02	10.7	2.44	13.2	24.9	18.8	11.8	1.24	0.31	8
9	0.09	0.03	0.05	0.02	6.72	2.17	27.1	50.1	15.6	10.0	1.15	0.31	9
10	0.09	0.14	0.05	0.02	5.64	2.58	15.6	78.4	13.2	21.7	1.52	0.31	10
11	0.08	0.08	0.05	0.02	4.13	2.85	11.8	34.8	64.0	13.9	1.24	0.28	11
12	0.08	0.06	0.05	0.02	5.43	2.72	10.7	28.8	29.4	13.2	1.05	0.28	12
13	0.08	0.05	0.05	0.02	3.43	2.44	8.86	29.4	82.8	12.4	1.05	0.24	13
14	0.08	0.05	0.07	0.02	3.78	3.26	7.44	23.8	53.4	11.4	1.62	0.24	14
15	0.08	0.05	0.06	0.03	2.44	4.65	40.5	35.5	36.7	9.43	1.15	0.20	15
16	0.07	0.04	0.07	0.06	1.81	5.43	31.2	63.1	26.6	8.58	0.96	0.20	16
17	0.07	0.04	0.08	0.06	1.43	7.15	18.8	36.1	24.9	7.44	0.81	0.17	17
18	0.06	0.04	0.05	0.06	1.15	7.15	45.5	25.4	22.7	6.50	0.76	0.10	18
19	0.06	0.04	0.03	0.14	0.86	4.83	20.2	19.3	23.2	5.64	0.76	0.10	19
20	0.06	0.34	0.03	0.14	0.81	6.50	16.1	24.9	25.4	5.00	0.70	0.07	20
21	0.06	0.38	0.03	0.09	0.70	4.65	14.4	19.3	22.7	4.48	0.65	0.09	21
22	0.06	0.20	0.03	0.08	0.60	3.96	40.5	25.4	22.2	4.30	0.60	0.09	22
23	0.06	0.17	0.03	0.06	0.50	3.43	41.1	30.6	19.3	3.96	0.60	0.09	23
24	0.05	0.50	0.03	0.07	0.45	3.12	43.6	26.0	16.1	3.43	0.55	0.09	24
25	0.05	0.28	0.03	0.07	0.42	3.96	51.7	32.4	18.3	2.99	0.50	0.08	25
26	0.05	0.17	0.03	0.76	0.42	3.61	34.2	19.8	27.6	2.85	0.50	0.08	26
27	0.06	0.09	0.03	0.65	0.34	3.43	27.1	15.6	23.2	2.58	0.50	0.08	27
28	0.06	0.08	0.03	0.38	0.34	26.6	19.8	18.8	18.3	2.44	0.42	0.08	28
29	0.06	0.08	0.03	0.42	0.28	30.6	16.5	13.9	16.5	2.31	0.42	0.08	29
30	0.06		0.03	0.70	1.34	36.7	29.4	19.3	14.8	2.17	0.38	0.08	30
31	0.05		0.03		2.04		19.8	15.2		1.90		0.08	31
Total	2.37	3.27	1.44	3.97	110.92	206.79	844.4	927.5	784.3	257.73	30.47	6.37	
Mean	0.08	0.11	0.05	0.13	3.58	6.89	27.2	29.9	26.1	8.31	1.02	0.21	

Annual Total ( )

Daily Discharge STATION BAN KHLONG SI SOOK

Klong Tha Dan RIVER, IN THE BASIN OF ______ ELEVATION ______ UNIT m^3/sec YEAR 1969

DATE	Jan.	Feb	Mar.	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	0.09	0.03	0.01	0.01	0.00	7.90	73.8	38.9	14.2	24 8	7.38	1.40	1
2	0.09	0.03	0.01	0.01	0.00	31.0	64.0	54 6	13.7	22.9	8.86	1.40	2
3	0.09	0 05	0.01	0.00	0.01	3.68	48.2	44.2	59.3	20.5	7 90	1.31	3
4	0 08	0.03	0.01	0.00	0.01	3.36	71.4	32.4	89.0	16.0	6.60	1 22	4
5	0.08	0.03	0 00	0.01	0.01	1.67	26.0	47.2	184	13.3	6.08	1.22	5
6	0.08	0.02	0.00	0.00	0.01	4.22	36.4	45 2	77.6	11.1	5 30	1.16	6
7	0.11	0.02	0.00	0.00	0.01	10.8	43.2	67 7	42.2	9.82	4.94	1.09	7
8	0 08	0.02	0.00	0.00	0 02	27.3	72.6	139	31.0	8 54	4 40	1.02	8
9	0 08	0.02	0.00	0 00	0.06	20.5	89.0	56.9	22.3	7.38	4.04	0.96	9
10	0.08	0.02	0.00	0.00	0.18	21.7	45.2	41.4	21.7	6.60	3.68	0.90	10
11	0 07	0.02	0.00	0.01	0.12	25.4	23.6	38 9	18 0	5.82	3.50	0.90	11
12	0.06	0.02	0.00	0.00	0.10	33.2	42.2	41.4	16.0	5.56	3.22	0.83	12
13	0.06	0.02	0 00	0.00	0.09	25 4	65 2	44.2	14.2	7.38	3.09	0.76	13
14	0.06	0.01	0.00	0 00	0.07	21.7	39.7	28.1	29.5	6 60	2.95	0.76	14
15	0 06	0.01	0.00	0 00	0.06	12.0	24.8	23.6	16.5	7.38	2.81	0.76	15
16	0.06	0.01	0.07	0.00	0 06	8.86	17.0	21.7	26.0	8.22	2.67	0.70	16
17	0 06	0.01	0.03	0.00	0.03	6.86	25.4	21.7	21.1	7.64	2.53	0.64	17
18	0.06	0 01	0 04	0 00	0.03	5.82	64.0	22.9	18.0	7.38	2.26	0.64	18
19	0.06	0 01	0.03	0.00	0.02	7 90	73.8	18.0	35.6	7 38	2.12	0 64	19
20	0.07	0.01	0.02	0.00	0.02	16.5	47.2	14.6	29.5	6.08	2.12	0.57	20
21	0 06	0.01	0.02	0.00	0.02	15.5	25.4	12.9	139	6 86	1.94	0.54	21
22	0 06	0.01	0.02	0.00	0.02	8.86	17.0	11.5	61.6	8.86	1,85	0 54	22
23	0.06	0.01	0.08	0 00	0 02	6.86	12.4	10.5	33.9	9.82	1.76	0.51	23
24	0.06	0.01	0.04	0.00	0.03	7.38	725	9.18	26 6	10.5	1 67	0.48	24
25	0.06	0.01	0.03	0 00	0 02	12.9	179	7.90	22.3	9.18	1.67	0.48	25
26	0 06	0.01	0.02	0.00	0.02	9.82	34.7	7.12	18.0	8.22	1 49	0 48	26
27	0.04	0.01	0.02	0.00	0.03	7.38	73.8	6.34	16.0	8.22	1 49	0 48	27
28	0.03	0.01	0.01	0.00	0.04	72.6	75 1	6 34	20.5	6 60	1 31	0.45	28
29	0.03		0 01	0.00	0.22	33.2	160	7.64	18.0	6.34	1.31	0.42	29
30	0.03		0.01	0 00	0.40	87 7	45.2	8.22	15 5	6.08	1.31	0.42	30
31	0 03		0 01		1.85		42.2	19.0		7.38		0.42	31
Total	2.00	0.48	0.46	0.04	3.58	557.97	2,382.5	949.24	1,150.8	298.44	102 25	24.10	
Mean	0.06	0 02	0 01	0 00	0 12	18.60	76.9	30.6	38.4	9.63	3.41	0.78	

Annual Total ( )

A - 4 (C)

Daily Mean and Monthly Mean Evaporation STATION BAN KHLONG SI SOOK CATCHMENT AREA ____ sq·km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	ANNUAL
1965					5.0	3.2	4.3	3.7	4.1	3.8	4.0	4.6	
1966	4.9	5.1	6.4	7.4	4.7	5.4	4.8	5.0	4.2	3.8	4.3	4.1	
1967	4.7	5.7	6.8	5.9	4.8	4.6	4.4	3.7	4.0	3.8	4.1	4.8	
1968	5.1	5.2	5.6	5.3	5.1	4.5	4.7	4.3	4.3	4.4	4.1	4.6	
1969	4.5	5.5	5.9	5.5	4.4	3.8	3.5	3.5	3.5	3.5	3.8	4.4	
1970	4.7	4.5	5.1	4.9	4.5	4.0	3.3	3.4	3.5	3.1	4.0	3.7	
Total	23.9	26.0	29.8	29.0	28.5	25.5	25.0	23.6	23.6	22.4	24.3	26.2	
Mean	4.8	5.2	5.9	5.8	4.7	4.2	4.1	3.9	3.9	3.7	4.1	4.4	4.6
1965					154.0	97.0	132.0	114.0	124.0	118.0	120.0	143.0	
1966	152.9	142.5	197.6	221.3	146.9	163.0	147.4	155.5	126.2	117.2	129 5	127.9	
1967	146.4	160.1	210.8	176.9	148.4	137.9	136.6	113.3	119.7	116.6	121.6	149.0	
1968	158.1	149.6	172 8	159 1	157.9	134.7	144.9	132.1	128.5	135.2	124.6	142.0	
1969	140 2	154.1	181.7	164.6	134.7	113.4	108.3	107.3	105.9	109.2	116.2	135.4	
1970	144.9	126.0	157.5	145.9	139.4	119.4	101.1	103.8	104.8	95.4	120.7	114.4	
Total	742.5	32.3	920.4	867.8	881.3	765.4	770.3	726.0	709.1	691.6	732.6	811.7	
Mean	148.5	146.5	184.0	173.6	146.2	127.6	128.4	121.0	118.2	115.3	122.1	135.3	1,666.7 (138.8)

Daily Evaporation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ____ ELEVATION ____ UNIT mm YEAR 1965

DATE	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec	DATE
1					5	5	4	3	4	4	8	6	1
2					7	7	3	3	5	7	3	5	2
3					7	4	4	4	2	4	4	4	3
4					5	6	3	2	4	1	3	4	4
5					4	5	8	3	3	4	5	4	5
6					4	2	6	3	4	3	3	4	6
7					4	4	6	2	4	4	3	4	7
8					5	2	5	4	5	6	6	4	8
9					4	4	4	3	4	0	3	5	9
10					5	4	5	10	9	4	4	5	10
11					5	4	5	5	3	4	4	5	11
12					6	2	7	4	6	3	4	4	12
13					5	3	1	3	4	4	5	4	13
14					5	2	2	6	2	3	4	6	14
15					4	2	8	4	6	3	5	5	15
16					9	1	4	2	3	4	3	5	16
17					4	2	7	6	3	4	5	4	17
18					4	3	3	2	3	5	3	5	18
19					5	4	2	6	5	4	3	4	19
20					6	3	6	3	7	3	5	5	20
21					4	1	4	6	4	5	3	3	21
22					3	3	5	3	2	4	3	3	22
23					6	2	6	4	4	2	5	4	23
24					7	3	3	4	5	3	3	6	24
25					3	1	3	3	5	4	3	5	25
26					5	2	2	4	2	5	3	5	26
27					5	3	3	4	7	5	5	3	27
28					1	4	2	2	4	5	3	7	28
29					4	6	2	1	2	6	4	5	29
30					6	3	5	3	3	3	5	5	30
31					7		4	2		2		5	31
Total Mean					154 5.0	97 3.2	132 4.3	114 3.7	124 4 1	118 3.8	120 4.0	143 4 6	

Annual Total ( )

Daily Evaporation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ____ ELEVATION ____ UNIT mm YEAR 1966

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	5.1	5.0	6.7	10.6	8.0	5.0	4.0	4 6	2.9	5.0	4 0	4.5	1
2	5.2	4.7	6.5	7 0	7.5	6.0	2.0	4.2	4.1	6.0	4.9	4 5	2
3	5.4	5.0	5.0	8 0	6 2	3 9	2 5	2 0	1.9	5.0	6.0	4.0	3
4	5 0	5.0	7 0	8 0	4.0	8.0	4.5	2.2	2.8	6 0	4.6	4.0	4
5	5.0	6 1	6.0	10.3	2.0	3.1	3 0	4.7	4.7	3.1	5 5	4.0	5
6	5.2	5.0	6.2	8 0	3.2	6.1	5.2	3.9	3.6	4.3	5.0	4.9	6
7	5.0	5.1	7.0	7.3	1.1	3.5	7.0	4.5	5 9	3.9	4.9	4.0	7
8	4.9	5 4	6 5	6.2	9.5	6.0	4.8	3.7	2.4	3.9	4.5	4.8	8
9	5.2	6.0	7.3	10.0	4.6	5 6	5.1	4.0	3.7	3 6	4 8	4.9	9
10	4 8	6.2	6 2	10.0	5.0	4.8	7.0	4.5	3.6	3 2	4.1	4.7	10
11	4.0	6 0	5.0	6.0	8.0	4.9	6.0	7.3	5.1	3.5	5.2	4 0	11
12	4 0	5.0	5.0	7 0	6 0	4 8	3 0	7 3	2 8	3 6	5 8	4.3	12
13	5 3	5 0	5.4	7 0	6.5	2 5	6 2	11.3	4.4	4 1	5.1	3.7	13
14	5 4	5.5	5.0	6 0	5 1	7.2	11.0	4.2	4.0	4.9	3.0	6.2	14
15	5.5	6.0	5.5	6.7	3.5	5 6	5 0	1 3	3.9	3.9	3 9	3.4	15
16	6.3	5 0	5 1	5.0	4.9	5 0	4.7	10.5	8.2	2.9	3.1	3.1	16
17	5.0	5.5	3.7	9 0	2 1	8 8	4.7	4 3	2.6	2.6	5.2	4.0	17
18	5 0	6.2	5.0	6.0	2.1	5 3	3 6	4 8	5 5	5 8	4 6	4.0	18
19	5 0	6.0	6 1	6.8	4.7	10 5	4 9	3 8	2 3	2 3	3 7	4 3	19
20	5 9	3.5	7.2	10.1	4 6	5 8	5 0	5.2	4 3	4 3	4 0	4 0	20
21	6 3	6 0	8 0	7.6	3 5	6.0	6.1	5.7	3.2	5.8	5.1	2.2	21
22	5 0	5 1	10.0	5.5	3.9	9 0	7 0	7.0	5 8	4.5	5 2	3 1	22
23	4.6	0 4	7.0	6.2	4.0	3.0	4.0	3.0	6 0	0 1	5 0	4 0	23
24	5.0	5.0	7.5	6 2	0 7	3 0	4 0	6.0	4.3	1.0	4 0	3 8	24
25	4 0	0 0	8 0	6.3	3.6	3 5	2 0	4.2	4 0	2 1	4 4	3.0	25
26	4.0	6.5	9 5	7.0	5.9	3.4	3.6	4.0	5.0	3.0	1.7	4 3	26
27	4.0	6.3	5.5	7.2	4.7	6.0	2.0	3.6	6 6	4 6	2 3	4.4	27
28	4.0	6.0	8.0	5.0	4.4	6.4	4.5	3.5	5.7	2.6	2.9	3.9	28
29	4.2		7 5	7.2	8.3	6.3	5.0	10.7	3 9	3.0	5.0	4 0	29
30	5.0		6.0	8 1	4 0	4 0	4.0	6 1	3.0	4.6	2 0	4 3	30
31	4.6		3.2		5.3		6.0	3.4		4 0		5.6	31
Total	152.9	142.5	197.6	221.3	146.9	163 0	147.4	155 5	126.2	117.2	129.5	127.9	
Mean	4.9	5.1	6.4	7.4	4 7	5 4	4.8	5 0	4.2	3 8	4.3	4 1	

Annual Total ( )

Daily Evaporation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1967

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	DATE
1	4.1	1.9	6.8	8.4	5.4	4.8	5.8	5.2	1.5	1.0	4.9	3.0	1
2	4.4	3.0	5.6	6.8	5.0	0.7	2.3	3.7	2.8	1.6	5.1	5.5	2
3	5.0	6.2	6.1	7.0	5.2	1.9	3.8	4.3	5.3	3.5	4.8	4.9	3
4	4.0	5.9	6.5	8.3	5.1	2.0	5.3	3.3	8.0	4.5	5.5	5.2	4
5	2.0	5.8	6.8	6.3	5.5	1.9	8.7	2.8	5.0	3.0	4.2	4.0	5
6	4.3	5.4	4.2	5.8	7.0	2.5	4.6	3.2	3.0	3.2	5.1	3.3	6
7	5.9	6.0	4.2	6.5	5.0	1.3	5.6	2.2	6.2	4.0	5.0	3.9	7
8	3.9	6.4	6.8	5.3	3.3	3.5	6.6	4.2	4.7	3.9	4.3	3.7	8
9	5.8	5.7	7.0	6.1	4.0	3.3	2.8	6.4	3.9	2.5	5.2	4.0	9
10	5.0	4.0	6.9	8.0	4.8	4.9	3.0	5.2	4.3	1.4	4.5	5.4	10
11	5.0	5.5	6.2	6.5	4.1	9.1	5.3	6.4	3.0	1.7	3.5	5.3	11
12	5.9	5.7	7.0	9.0	4.4	4.1	4.1	2.5	3.5	5.1	1.7	4.7	12
13	5.0	5.8	5.3	8.0	6.6	3.4	7.7	3.5	4.7	4.3	2.2	4.8	13
14	5.0	6.8	5.9	6.0	4.1	3.0	2.0	3.7	4.4	3.6	4.5	4.9	14
15	5.2	6.5	6.0	4.5	6.2	6.0	2.1	4.5	4.0	4.4	4.4	4.9	15
16	5.0	6.5	7.5	4.9	3.2	4.0	2.9	4.4	2.8	4.7	3.9	5.4	16
17	4.6	6.7	5.8	3.0	4.2	9.5	3.3	1.5	1.0	6.0	4.3	5.0	17
18	4.6	6.9	7.6	5.3	3.4	3.3	2.3	3.1	4.0	4.7	4.4	4.3	18
19	5.7	6.7	7.0	5.0	5.0	5.5	4.3	5.4	3.3	3.0	3.6	5.0	19
20	5.0	6.0	7.8	6.0	4.9	6.6	7.5	2.8	4.1	4.6	2.8	5.5	20
21	4.7	4.6	6.8	5.5	6.0	6.4	8.0	3.1	2.5	4.0	3.0	4.8	21
22	5.0	4.1	8.3	3.0	4.3	6.0	5.0	3.0	3.0	4.1	5.0	5.9	22
23	5.0	6.1	7.8	6.1	4.5	5.7	3.5	3.4	5.0	4.0	3.8	5.4	23
24	5.0	5.9	8.0	5.0	2.1	4.2	5.3	4.1	3.2	3.3	4.4	4.9	24
25	3.0	7.3	6.9	6.0	5.9	5.0	4.1	3.6	6.2	3.8	3.8	4.8	25
26	4.1	5.7	7.2	5.5	5.9	6.0	4.0	1.6	5.6	4.0	4.5	5.8	26
27	4.7	6.0	7.3	4.4	5.3	5.1	2.2	2.4	3.5	4.3	4.0	4.9	27
28	5.7	7.0	7.8	3.4	4.4	5.1	2.8	4.0	4.9	4.7	3.2	4.9	28
29	4.0		8.2	5.8	3.3	6.6	3.4	1.9	2.3	3.9	2.2	4.7	29
30	6.5		7.9	5.5	6.3	6.5	5.5	3.3	4.0	4.8	3.8	5.0	30
31	3.3		7.6		4.0		2.8	5.2		5.0		5.2	31
Total	146.4	160.1	210.8	176.9	148.4	137.9	136.6	113.3	119.7	116.6	121.6	149.0	
Mean	4.7	5.7	6.8	5.9	4.8	4.6	4.4	3.7	4.0	3.8	4.1	4.8	

Annual Total ( )

Daily Evaporation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ELEVATION UNIT mm YEAR 1968

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	DATE
1	5.7	6.0	5.0	7.2	4.3	5.9	4.7	7.1	6.2	3.3	4.8	3.0	1
2	4.8	4.9	4.6	7.4	5.7	3.4	3.2	6.4	5.2	3.3	4.4	4.7	2
3	4.3	5.6	4.0	6.9	2.7	2.2	3.4	4.1	4.8	5.2	4.0	5.0	3
4	4.7	5.0	4.4	6.7	3.2	2.5	6.6	3.1	5.1	3.7	4.2	3.7	4
5	4.6	5.1	5.0	4.1	4.1	5.0	3.8	4.6	5.7	3.9	4.8	3.8	5
6	4.5	6.2	5.7	5.1	6.2	5.3	2.0	4.0	2.2	3.8	3.8	2.5	6
7	5.0	6.0	5.1	6.4	3.1	5.5	5.8	2.4	1.5	4.3	4.8	4.8	7
8	5.4	5.6	6.7	6.0	4.1	6.3	6.6	8.0	3.0	3.5	3.9	4.8	8
9	4.6	6.6	5.3	5.9	2.9	5.1	3.6	6.3	4.6	5.4	2.8	5.4	9
10	4.6	6.6	6.2	7.1	4.8	4.9	3.8	1.6	3.4	5.0	3.4	2.8	10
11	5.0	5.4	5.9	6.9	4.5	3.8	6.5	3.0	5.4	2.9	5.6	4.3	11
12	4.8	2.2	4.8	6.3	5.9	3.3	4.0	1.6	9.1	3.9	4.6	5.5	12
13	5.2	5.3	3.6	7.0	5.9	2.9	3.9	1.3	3.1	5.1	4.1	4.5	13
14	4.8	4.7	5.0	4.2	5.3	4.2	5.0	3.4	4.1	4.6	3.3	5.4	14
15	5.3	4.9	5.8	4.9	7.0	3.7	7.0	2.4	4.5	3.6	4.0	5.2	15
16	5.6	5.0	4.9	4.8	5.8	6.2	4.2	4.0	2.8	6.4	4.0	5.0	16
17	5.7	5.1	5.3	6.1	6.5	1.9	5.0	2.8	4.2	3.0	4.7	4.6	17
18	5.0	5.9	5.6	4.2	6.5	3.7	4.8	4.5	2.3	4.7	4.4	3.9	18
19	5.1	7.2	5.7	4.5	6.3	6.3	4.6	5.5	5.1	5.2	3.9	4.0	19
20	5.6	5.8	4.9	4.3	6.6	4.7	4.2	4.0	3.7	5.7	4.6	4.5	20
21	5.7	5.9	6.5	5.0	5.3	4.0	7.2	3.5	2.9	3.6	4.6	4.9	21
22	4.1	5.4	6.7	6.4	4.9	5.0	7.1	2.5	5.5	3.4	4.9	5.7	22
23	4.5	6.4	5.3	5.1	5.5	4.8	3.6	2.8	3.2	4.4	4.6	5.9	23
24	4.7	2.0	6.5	2.3	5.9	5.7	6.3	4.3	5.2	4.5	4.4	6.0	24
25	4.8	3.9	5.7	3.2	5.0	3.9	3.4	5.3	5.6	4.0	2.2	5.2	25
26	6.5	5.3	6.0	2.6	4.9	4.6	3.9	6.3	4.5	4.3	4.7	5.0	26
27	5.8	3.6	7.4	4.4	5.4	7.2	3.0	5.4	4.5	5.3	3.5	4.3	27
28	5.9	4.0	5.5	5.6	5.0	4.4	2.7	4.9	3.0	5.0	3.0	4.6	28
29	5.8	4.0	6.7	2.5	5.5	2.0	6.0	6.9	3.5	5.2	4.8	3.9	29
30	5.0		6.5	6.0	4.0	6.3	4.6	5.0	4.6	4.2	3.8	4.2	30
31	5.0		6.5		5.1		4.4	5.1		4.8		4.9	31
Total	158.1	149.6	172.8	159.1	157.9	134.7	144.9	132.1	128.5	135.2	124.6	142.0	
Mean	5.1	5.2	5.6	5.3	5.1	4.5	4.7	4.3	4.3	4.4	4.1	4.6	

Annual Total ( )

Daily Evaporation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ____ ELEVATION ____ UNIT mm YEAR 1969

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	4 8	3.8	6.4	6.0	6.3	3.1	7.5	4.0	5.7	3.1	1.5	4.2	1
2	5.0	3.1	6.8	6.8	6.4	3.9	3.3	2.2	5.3	3.2	2.0	5.3	2
3	5.5	4.9	6.7	7.0	4.3	3.8	3.5	3.5	0.7	1.4	2.8	5.0	3
4	4.8	4.1	5.9	6 8	5.0	3.4	3.0	3.8	6.3	3.7	3.7	4.3	4
5	5.0	4.8	6 5	3.0	6.7	5.8	6.5	1.0	4.4	2.3	5.2	4.0	5
6	0.9	5.4	5.8	5.6	4.5	5 8	3.7	3.0	2.8	2.8	4.0	4.0	6
7	3.6	5.5	6.2	6.6	3.7	5.3	5.3	2.5	1.0	3.5	3.2	4.2	7
8	4.4	5.0	6.6	5.9	3.1	3.6	1.0	1.6	4.0	4.8	4.0	6.7	8
9	5.9	5.5	6.3	5.1	4.5	3.4	4.5	1.4	2.6	3.5	3.9	4.0	9
10	5.0	4.9	6.8	5.4	6.0	3.4	2.7	2.7	2.8	4.4	5.9	4 0	10
11	5.1	5.9	6.9	3.0	4.0	7.0	4.1	2.7	3.0	5.6	4.8	4.0	11
12	6.0	6.0	5.7	3.5	5.8	4.9	3 0	2.9	4.4	3.6	4 3	4 0	12
13	4.9	5.7	4.8	4.6	7.2	3.4	6.1	3.0	5.2	3.0	4.0	4.0	13
14	4.6	5.6	6.0	4.7	5.4	4 0	4.4	2.6	4 2	2.2	4.8	4.0	14
15	4.4	5.9	3.2	5.9	6.5	3.5	3.0	4.3	3.4	3.5	2.4	4 0	15
16	4.7	5.4	5.0	5 3	4.3	1.0	6.7	4.0	1.7	3.0	4.0	3.7	16
17	3.1	6.0	3.2	5.7	4.0	2.8	3.2	2.7	1.5	4.6	3.0	4.0	17
18	4.2	5.6	1.0	5.9	4 0	2.0	4.1	4.0	4.4	3.9	4.3	4.9	18
19	4.3	6.2	7.2	5.0	2.5	3.8	1 4	3.7	2.4	4.0	3.2	4.6	19
20	3.9	6 8	7.0	5.8	4.7	2 8	3.1	4.2	3 0	4.2	4 0	4.0	20
21	5 0	7.2	6.8	7.6	4.3	3 0	2.4	3.5	1.0	4.0	3.7	4.6	21
22	4.4	6.7	7.2	7.5	2.6	4.0	2.4	3.0	4 0	4.0	4.0	4.2	22
23	4 8	3.9	6.1	4.9	4.0	4.0	4.5	3.4	4.6	3 3	3.0	4.2	23
24	4.2	6.7	6.2	5 0	5.1	3.5	1 0	5.0	4.7	4.2	3.8	4.3	24
25	3.0	6 2	5.0	6.0	4.9	1.6	2.0	5.4	3.6	4.0	3.5	3.2	25
26	4.1	5.2	6.0	5.8	4.0	2.0	3 3	5 0	2.3	2.6	4.8	3.9	26
27	4.0	6.3	6.9	7.2	2.4	4.1	2.6	4.0	5.3	3.0	5.8	4.8	27
28	5.2	5.8	5.8	2 9	3.1	4.8	4.1	4.6	3.7	3.7	5.0	4 0	28
29	5.2		6 0	6.5	1.0	3 8	1.0	4.7	3.1	3.6	3.2	5 8	29
30	4.7		5.9	3.6	2.2	5.9	1.6	5.4	4.8	3.5	4.4	4.0	30
31	5.5		5.8		2.2		3 3	3.5		3.0		5.5	31
Total	140.2	154.1	181.7	164.6	134.7	113.4	108.3	107.3	105.9	109.2	116.2	135.4	
Mean	4.5	5.5	5.9	5.5	4.3	3.8	3.5	3.5	3.5	3.5	3.9	4.4	

Annual Total ( )

Daily Evaporation STATION BAN KHLONG SI SOOK

RIVER, IN THE BASIN OF ____ ELEVATION ____ UNIT mm YEAR 1970

DATE	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	DATE
1	4.0	5.3	4.8	4.4	4.5	3.7	5.0	4.4	4 0	1.6	2.2	1.3	1
2	4.7	5.5	5.0	6 6	5.0	6.1	4.2	3.1	2 3	3.9	4.4	4.0	2
3	4.4	4.8	5.5	4.3	5.4	5.7	4.2	1.9	4.4	5 0	4.0	3.2	3
4	4.2	5.0	4.8	3.0	4.0	1 3	4.1	2.1	4.5	5 0	4.3	1.7	4
5	3.2	5 3	4 2	4.1	3 7	4.4	1 5	2 8	3 2	7 0	4.0	2.0	5
6	4.4	5.0	4.5	4.0	5.9	6.9	3.6	1 4	5.0	4.0	4.5	3.0	6
7	4.0	5 2	5.6	4.5	4.0	6.9	2.7	2.7	2.3	2.0	4.0	5.0	7
8	4.5	4.4	5.5	4.9	4.7	4.0	3.4	5.5	3.5	1.8	3 0	3.0	8
9	5.0	5 5	5.4	3.0	6.4	3.4	3.2	4.8	1.9	4.5	3.6	3.9	9
10	3.5	3.9	5.7	5.0	4.3	4 1	2.2	4.3	1.8	4.1	4.0	3 0	10
11	5.2	0.0	5.8	6.6	6.5	4.4	3 6	4.0	3.3	3.8	4.0	4.0	11
12	5.2	2.4	6.0	6 0	5.7	3.5	1.0	5.1	4.3	2.9	3.1	2.8	12
13	4 0	2.2	5.8	4.0	5.8	3.0	2.5	5.4	3 0	2.8	4.0	3.7	13
14	3.5	3.9	5.4	6.4	4.2	2.4	0.5	2.4	3.0	3.0	7.3	3.6	14
15	4.5	4.9	5.8	4.9	3.1	3.1	3.9	4.7	3.9	2.8	4 0	3.8	15
16	5.0	2.8	6.3	5.0	3.2	4 6	1.0	1.2	4.8	5.2	3.5	4.8	16
17	6.7	4.5	6.8	5.7	3.1	4.3	1.7	3.6	4.6	2.6	4.5	4.6	17
18	4 2	4.3	5.3	6.0	2.1	2.8	0.7	2.9	3.9	2.0	3.1	4.2	18
19	4.7	4.8	5.7	5.6	2.7	6.1	3.0	3.3	3.7	1.4	4.0	4.2	19
20	5.2	4.3	4 6	6.4	1.6	2.8	3.2	1 7	3.5	3.3	4.3	5.0	20
21	4.2	5.4	5.0	5 4	3.0	3.1	3.0	3.3	3.1	4.5	3.8	5 0	21
22	4.8	5.0	3.9	4.8	2.2	4.9	4.8	5.0	2.6	1.9	2.5	3.0	22
23	5.2	5 3	1.5	5.6	4.8	3.9	4.9	3.3	3.4	3.0	3.6	3.0	23
24	3.3	5.5	4.3	4.6	5.2	3.4	3.0	2.0	4.0	2.0	4.0	1.0	24
25	5.0	5.2	3 0	4.3	6 4	5.6	3.4	4.0	4 3	3.7	4 0	3.6	25
26	4.0	5.4	4.3	2.3	7.2	1.6	2.2	3.4	3.2	1.9	4.5	4.9	26
27	5.0	5.0	4.4	5.0	5 0	2.2	4.8	3.1	4.0	2.2	4.0	4.5	27
28	6.0	5.2	6.0	4.5	5 0	4.2	3.2	3.0	4.4	3.2	4 0	4.8	28
29	6.0		5.2	4.0	3.0	3.2	6 4	2.0	1.9	2.0	7.4	3 2	29
30	6.2		6.2	5.0	6.0	3.8	4.0	4.4	3.0	0.9	3.1	5.6	30
31	5.1		5.2		5.7		6.2	3.0		1.4		5 0	31
Total	144.9	126.0	157.5	145.9	139.4	119.4	101.1	103.8	104.8	95.4	120.7	114.4	
Mean	4.7	4.5	5.1	4.9	4.5	4.0	3 3	3.4	3.5	3.1	4.0	3.7	

Annual Total ( )